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AMERICAN SOCIETY
FOR
TESTING MATERIALS.

AFFILIATED WITH THE
INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

SELECTED
STANDARD SPECIFICATIONS.

OFFICE OF THE SECRETARY-TREASURER, UNIVERSITY OF PENNSYLVANIA,
PHILADELPHIA, PA.

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SELECTED
STANDARD SPECIFICATIONS

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

CARBON-STEEL RAILS.

Serial Designation: A1–14.

The specifications for this material are issued under the fixed designation A1; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1907, 1908, 1909, 1914.

INSPECTION.

Access to Works.

1. Inspectors representing the purchaser shall have free entry to the works of the manufacturer at all times while the contract is being executed, and shall have all reasonable facilities afforded them by the manufacturer to satisfy them that the rails have been made and loaded in accordance with the terms of the specifications.

Place of Tests.

2. All tests and inspections shall be made at the place of manufacture, prior to shipment and shall be so conducted as not to interfere unnecessarily with the operations of the mill.

MATERIAL.

Material.

3. The material shall be steel made by the Bessemer or open-hearth process, as provided by the contract.

CHEMICAL REQUIREMENTS.

Chemical Composition.

4. The chemical composition of each heat of the steel from which the rails are rolled, determined as prescribed in Section 6, shall be within the following limits:

BESSEMER STEEL.

Elements Considered.	Weights, lb. per yd.			
	50 – 69, incl.	70 – 84, incl.	85 – 100, incl.	101 – 120, incl.
Carbon, per cent.....	0.37 – 0.47	0.40 – 0.50	0.45 – 0.55	0.45 – 0.55
Manganese, per cent.....	0.80 – 1.10	0.80 – 1.10	0.80 – 1.10	0.80 – 1.10
Phosphorus, max., per cent	0.10	0.10	0.10	0.10
Silicon, max., per cent....	0.20	0.20	0.20	0.20

OPEN-HEARTH STEEL.

Carbon, per cent.....	0.50 – 0.63	0.53 – 0.66	0.62 – 0.75	0.62 – 0.75
Manganese, per cent.....	0.60 – 0.90	0.60 – 0.90	0.60 – 0.90	0.60 – 0.90
Phosphorus, max., per cent	0.04	0.04	0.04	0.04
Silicon, max., per cent....	0.20	0.20	0.20	0.20

5. It is desired that the percentage of carbon in an entire order of rails shall average as high as the mean percentage between the upper and lower limits specified. **Average Carbon.**

6. In order to ascertain whether the chemical composition is in accordance with the requirements, analyses shall be furnished as follows: **Analyses.**

(*a*) For the Bessemer process, the manufacturer shall furnish to the inspector, daily, carbon determinations for each heat before the rails are shipped, and two chemical analyses every 24 hours representing the average of the elements, carbon, manganese, silicon, phosphorus, and sulfur contained in the steel, one for each day and night turn respectively. These analyses shall be made on drillings taken from the ladle test ingot not less than $\frac{1}{8}$ in. beneath the surface.

(*b*) For the open-hearth process the manufacturer shall furnish the inspector with a chemical analysis of the elements, carbon, manganese, silicon, phosphorus, and sulfur for each heat.

(*c*) On request of the inspector, the manufacturer shall furnish a portion of the test ingot for check analysis.

PHYSICAL REQUIREMENTS.

7. Tests shall be made to determine: **Physical Qualities.**

(*a*) Ductility or toughness as opposed to brittleness;

(*b*) Soundness.

Method of testing.

8. The physical qualities shall be determined by the drop test.

Drop-Testing Machine.

9. The drop-testing machine shall be the standard of the American Railway Engineering Association.

(*a*) The tup shall weigh 2000 lb., and have a striking face with a radius of 5 in.

(*b*) The anvil block shall weigh 20,000 lb., and be supported on springs.

(*c*) The supports for the test pieces shall be a part of, or firmly secured to, the anvil. These supports shall be spaced 3 ft. between centers for rails 100 lb. per yd. or less in weight and 4 ft. for rails over 100 lb. per yd. in weight. The bearing surfaces of the supports shall have a radius of 5 in.

Pieces for Drop Tests.

10. Drop tests shall be made on pieces of rail not less than 4 ft. and not more than 6 ft. long. These test pieces shall be cut from the top end of the top rail of the ingot, and marked on the base or head with gage marks 1 in. apart for 3 in. each side of the center of the test piece, for measuring the ductility of the metal.

Temperature of Test Pieces.

11. The temperature of the test pieces shall be between 60 and 100° F.

Weight of Drop.

12. The test piece shall ordinarily be placed head upwards on the supports, and be subjected to impact of the tup falling free from the following heights:

Weight of Rail, lb. per yd.	Height of Drop, ft.
50 – 60 inclusive	15
61 – 79 "	16
80 – 90 "	17
91 – 100 "	18
101 – 120 "	21

Elongation or Ductility.

13. (*a*) Under impacts, the rail under one or more blows shall show at least 6 per cent elongation for one inch or 5 per cent each for two consecutive inches of the 6-in. scale, marked as described in Section 10.

(*b*) A sufficient number of blows shall be given to determine the complete elongation of the test piece of at least every fifth heat of Bessemer steel, and of one out of every three test pieces of a heat of open-hearth steel.

14. It is desired that the permanent set after one blow under the drop test shall not exceed that in the following table, and a record shall be made of the information: Permanent Set.

Section.	Weight, lb. per yd.	Moment of Inertia.	Permanent Set, in. (measured by middle ordinate in a length of 3 ft.).	
			Bessemer Process.	Open-Hearth Process.
A.R.A. – A.....	100	48.94	1.65	1.45
A.R.A. – B.....	100	41.30	2.05	1.80
A.R.A. – A.....	90	38.70	1.90	1.65
A.R.A. – B.....	90	32.30	2.20	2.00
A.R.A. – A.....	80	28.80	2.85	2.45
A.R.A. – B.....	80	25.00	3.15	2.85
A.R.A. – A.....	70	21.05	3.50	3.10
A.R.A. – B.....	70	18.60	3.85	3.50

15. Test pieces which do not break under the first or subsequent blows shall be nicked and broken, to determine whether the interior metal is sound. The words "interior defect" in the following sections shall be interpreted to mean seams, laminations, cavities, or interposed foreign matter made visible by the destruction test, saws or drills. Test to Destruction.

16. One piece shall be tested from each heat of Bessemer steel. Bessemer-Process Drop Test.

(*a*) If a test piece does not break at the first blow and shows the required elongation (Section 13), all the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(*b*) If, however, the test piece shows interior defect, the other test requirements having been met, all the top rails of the heat shall be accepted as special rails and further test shall be made on the second rails, as described in Paragraph (*d*) of this section.

(*c*) If the test piece breaks at the first blow or does not show the required elongation (Section 13), all the top rails of the heat shall be rejected.

(*d*) A second test shall then be made of the test piece selected by the inspector from the top end of any second rail

or the bottom end of any top rail of the same heat, preferably the same ingot. If the test piece does not break at the first blow and shows the required elongation (Section 13), all the remainder of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(*e*) If, however, the test piece shows interior defect, the other test requirements having been met, all the second rails of the heat shall be accepted as special rails and further test shall be made on the third rails, as described in Paragraph (*g*) of this section.

(*f*) If the test piece breaks at the first blow or does not show the required elongation (Section 13), all the second rails of the heat shall be rejected.

(*g*) A third test shall then be made of the test piece selected by the inspector from the top end of any third rail or the bottom end of any second rail of the same heat, preferably the same ingot. If the test piece does not break at the first blow and shows the required elongation (Section 13), all the remainder of the rails of the heat shall be accepted, provided that the test piece when broken does not show interior defect.

(*h*) If, however, the test piece shows interior defect, the other test requirements having been met, all the remainder of the rails of the heat shall be accepted as special rails.

(*i*) If the test piece breaks at the first blow or does not show the required elongation (Section 13), all the remainder of the rails of the heat shall be rejected.

pen-Hearth-rocess rop Test.

17. Test pieces shall be selected from the second, middle and last full ingot of each open-hearth heat.

(*a*) If two of these test pieces do not break at the first blow and both show the required elongation (Section 13), all of the rails of the heat shall be accepted, provided that none of the three test pieces when broken shows interior defect.

(*b*) If, however, any one of the three test pieces shows interior defect, the other test requirements having been met, all the top rails of the heat shall be accepted as special rails and further test shall be made on the second rails, as described in Paragraph (*d*) of this section.

(*c*) If two of the test pieces break at the first blow or do not show the required elongation (Section 13), all the top rails of the heat shall be rejected.

(*d*) A second test shall then be made from three test pieces selected by the inspector from the top end of any second rails or the bottom end of any top rails of the same heat, preferably the same ingots. If two of the test pieces do not break at the first blow and both show the required elongation (Section 13), all the remainder of the rails of the heat shall be accepted, provided that none of the three test pieces when broken shows interior defect.

(*e*) If, however, any one of the three test pieces shows interior defect, the other test requirements having been met, all the top rails of the heat shall be accepted as special rails and further test shall be made on the third rails, as described in Paragraph (*g*) of this section.

(*f*) If two of the test pieces break at the first blow or do not show the required elongation (Section 13), all the second rails of the heat shall be rejected.

(*g*) A third test shall then be made from three test pieces selected by the inspector from the top end of any third rails or the bottom end of any second rails of the same heat, preferably the same ingots. If two of the test pieces do not break at the first blow and both show the required elongation (Section 13), all the remainder of the rails of the heat shall be accepted, provided that none of the test pieces when broken shows interior defect.

(*h*) If, however, any one of the three test pieces shows interior defect, the other test requirements having been met, all the remainder of the rails of the heat shall be accepted as special rails.

(*i*) If two of the test pieces break at the first blow or do not show the required elongation (Section 13), all the remainder of the rails of the heat shall be rejected.

No. 1 Rails.

18. No. 1 classification rails shall be free from injurious defects and flaws of all kinds.

No. 2 Rails.

19. (*a*) Rails which by reason of surface imperfections, or for causes mentioned in Section 30 hereof, are not classed as No. 1 rails will be accepted as No. 2 rails; but No. 2 rails which contain imperfections in such number or of such character as will, in the judgment of the inspector, render them unfit for recognized No. 2 uses, will not be accepted for shipment.

(*b*) No. 2 rails to the extent of 5 per cent of the whole order will be received. All rails accepted as No. 2 rails shall have the ends painted white, and shall have two prick-punch marks on the side of the web near the heat number near the end of the rail, so placed as not to be covered by the splice bars.

pecial Rails. 20. Rails accepted as special rails in accordance with Sections 16 and 17, shall have the ends painted blue and shall have three prick-punch marks on the side of the web near the heat number, so placed as not to be covered by the splice bars.

DETAILS OF MANUFACTURE.

uality of anufacture. 21. The entire process of manufacture shall be in accordance with the best current state of the art.

ed Ingots. 22. Bled ingots shall not be used.

iscard. 23. There shall be sheared from the end of the bloom, formed from the top of the ingot, sufficient metal to secure sound rails.

engths. 24. The standard length of the rails shall be 33 ft., at a temperature of 60° F. Ten per cent of the entire order will be accepted in shorter lengths varying by 1 ft. from 32 to 25 ft. A variation of $\frac{1}{4}$ in. from the specified lengths will be allowed, except that for 15 per cent of the order a variation of $\frac{3}{8}$ in. from the specified lengths will be permitted. No. 1 rails less than 33 ft. long shall have the ends painted green.

hrinkage. 25. The number of passes and speed of the train shall be so regulated that on leaving the rolls at the final pass the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws, for a rail 33 ft. in length, and of 100-lb. section, of $6\frac{3}{4}$ in., and $\frac{1}{8}$ in. less for each 10-lb. decrease in section or $\frac{1}{8}$ in. more for each 10-lb. increase in section.

ooling. 26. The bars shall not be held for the purpose of reducing their temperature, nor shall any artificial means of cooling them be used after they leave the finishing pass. Rails, while on the cooling beds, shall be protected from snow and water.

ections. 27. The section of rails shall conform as accurately as possible to the templet furnished by the railroad company. A variation in height of $\frac{1}{64}$ in. less or $\frac{1}{32}$ in. greater than the specified height, and $\frac{1}{16}$ in. in width of flange, will be permitted;

but no variation shall be allowed in the dimensions affecting the fit of the splice bars.

28. The weight of the rails specified in the order shall be maintained as nearly as possible, after complying with Section 27. A variation of 0.5 per cent from the calculated weight of section, as applied to an entire order, will be allowed. Weight.

29. Rails accepted will be paid for according to actual weights. Payment.

30. (*a*) The hot-straightening shall be carefully done, so that gagging under the cold presses will be reduced to a minimum. Any rails coming to the straightening presses showing sharp kinks or greater camber than that indicated by the middle ordinate of 4 in. in 33 ft. for A. R. A. type of sections, or 5 in. for A. S. C. E. type of sections, will be at once classed as No. 2 rails. The distance between the supports of rails in the straightening presses shall not be less than 42 in. The supports shall have flat surfaces and be out of wind. Straightening.

(*b*) Rails heard to snap or check while being straightened shall be at once rejected.

31. Circular holes for joint bolts shall be drilled to conform to the drawing and dimensions furnished by the railroad company. A variation of $\frac{1}{32}$ in. larger than the specified size of holes will be allowed. Drilling.

32. (*a*) All rails shall be smooth on the heads, straight in line and surface, and without any twists, waves or kinks. They shall be sawed square at the ends, a variation of not more than $\frac{1}{32}$ in. being allowed, and burrs shall be carefully removed. Finishing.

(*b*) Rails improperly drilled or straightened, or from which the burrs have not been removed, shall be rejected, but may be accepted after being properly finished.

(*c*) When any finished rail shows interior defect at either end, or in any drilled hole, the entire rail shall be rejected.

33. (*a*) The name of the manufacturer, the weight and type of rail, and the month and year of manufacture, shall be rolled in raised letters and figures on the side of the web. The number of the heat and a letter indicating the portion of the ingot from which the rail was made, shall be plainly stamped on the web of each rail, where it will not be covered by the splice bars. The top rails shall be lettered "A," and the Branding.

succeeding ones "B," "C," "D," etc., consecutively; but in case of a top discard of 20 or more per cent, the letter "A" will be omitted. All markings of rails shall be done so effectively that the marks may be read as long as the rails are in service.

(*b*) Open-hearth rails shall be branded or stamped "O. H." in addition to the other marks.

Separate Classes.

34. All classes of rails shall be kept separate from each other.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

OPEN-HEARTH STEEL GIRDER AND HIGH TEE RAILS.

Serial Designation: A 2 – 12.

The specifications for this material are issued under the fixed designation A 2; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1912.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process. The entire process of manufacture and testing shall accord with the best current practice.

Bled Ingots. 2. Bled ingots, and ingots or blooms which show the effects of injurious treatment, shall not be used.

Discard. 3. A sufficient discard from the top of each ingot shall be made at any stage of the manufacture to obtain sound rails. When finished rails show piping, they may be cut to shorter lengths until all evidence of this is removed.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 4. The steel shall conform to either of the following requirements as to chemical composition, as specified in the order:

	Class A.	Class B.
Carbon, per cent	0.60 – 0.75	0.70 – 0.85
Manganese, per cent	0.60 – 0.90	0.60 – 0.90
Silicon, per cent	not over 0.20	not over 0.20
Phosphorus, per cent	" " 0.04	" " 0.04

Ladle Analyses.

5. To determine whether the material conforms to the requirements specified in Section 4, an analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt. Drillings for analysis shall be taken not less than $\frac{1}{8}$ in. beneath the surface of the test ingot. A copy of this analysis shall be given to the purchaser or his representative.

Check Analyses.

6. A check analysis may be made from time to time by the purchaser from a test ingot or drillings therefrom furnished by the manufacturer.

III. PHYSICAL PROPERTIES AND TESTS.

Drop Tests.

7. (*a*) The test specimen shall be tested on a drop-test machine of the type recommended by the American Railway Engineering Association. The specimen shall be placed head upwards on the supports of the machine, and shall not break when tested with one blow in accordance with the following conditions:

Weight and Height of Rail.	Temperature of Specimen, deg. Fahr.	Distance between Supports, ft.	Weight of Tup, lb.	Height of Drop.	
				Class A	Class B
Rails weighing over 100 lb. per yd. and over 7 in. in depth	60 – 120	3	2000	15	12
All other sections	60 – 120	3	2000	13	10

(*b*) The atmospheric temperature at the time of testing shall be recorded in the test report.

(*c*) The testing shall proceed concurrently with the operation of the works.

Test Specimens.

8. (*a*) Three rails, each from the top of one of three ingots from each melt, shall be selected by the inspector, and a test specimen shall be taken from each of two of these.

(*b*) Drop test specimens shall not be less than 4 nor more than 6 ft. in length.

Number of Tests.

9. Two drop tests shall be made from each melt.

Retests.

10. If the result of the drop test on only one of the two specimens representing the rails in a melt, does not conform to the requirements specified in Section 7, a retest on a specimen

from the third rail selected shall be made and this shall govern the acceptance or rejection of the rails from that melt.

IV. STANDARD SECTIONS, LENGTHS, AND WEIGHTS.

Section. 11. (*a*) The cold templet of the manufacturer shall conform to the specified section as shown in detail on the drawing of the purchaser, and shall at all times be maintained perfect.

(*b*) The section of the rail shall conform as accurately as possible to the templet, and within the following tolerances:

(1) The height shall not vary more than $\frac{1}{64}$ in. under nor more than $\frac{1}{32}$ in. over that specified.

(2) The over-all width of head and tram shall not vary more than $\frac{1}{8}$ in. from that specified. Any variation which would affect the gage line more than $\frac{1}{32}$ in. will not be allowed.

(3) The width of base shall not vary more than $\frac{1}{8}$ in. under that specified for widths less than $6\frac{1}{2}$ in.; $\frac{3}{16}$ in. under for a width of $6\frac{1}{2}$ in.; and $\frac{1}{4}$ in. under for a width of 7 in.

(4) Any variation which would affect the fit of the splice bars will not be allowed.

(5) The base of the rail shall be at right angles to the web; and the convexity shall not exceed $\frac{1}{32}$ in.

(*c*) When necessary on account of the type of track construction, and notice to that effect has been given to the manufacturer, special care shall be taken to maintain the proper position of the gage line with respect to the outer edge of the base.

Length. 12. (*a*) Unless otherwise specified, the lengths of rails at a temperature of 60° F. shall be 60 and 62 ft. for those sections in which the weight per yard will permit.

(*b*) The lengths shall not vary more than $\frac{1}{4}$ in. from those specified.

(*c*) Shorter lengths, varying by even feet down to 40 ft., will be accepted to the extent of 10 per cent by weight of the entire order.

Weight. 13. (*a*) The weight of the rails per yard as specified in the order shall be maintained as nearly as possible after conforming to the requirements specified in Section 11.

(*b*) The total weight of an order shall not vary more than 0.5 per cent from that specified.

(*c*) Payments shall be based on actual weights.

V. WORKMANSHIP AND FINISH.

Straightening. 14. (*a*) Rails on the hot beds shall be protected from water or snow, and shall be carefully manipulated to minimize cold straightening.

(*b*) The distance between the rail supports in the cold-straightening presses shall not be less than 42 in., except as may be necessary near the ends of the rails. The gag shall have rounded corners to avoid injury to the rails.

Drilling and Punching. 15. (*a*) Circular holes for joint bolts, bonds, and tie rods shall be drilled to conform to the drawings and dimensions furnished by the purchaser.

(*b*) In Class A rails the tie-rod holes may be punched.

Milling. 16. The ends shall be milled square laterally and vertically, but the base may be undercut $\frac{1}{32}$ in.

Finish. 17. (*a*) Rails shall be smooth on the head, straight in line and surface without any twists, waves, or kinks, particular attention being given to having the ends without kinks or drop.

(*b*) All burrs or flow caused by drilling or sawing shall be carefully removed.

(*c*) Rails shall be free from gag marks and other injurious defects of cold-straightening.

VI. CLASSIFICATION OF RAILS.

No. 1 Rails. 18. Rails which are free from injurious defects and flaws of all kinds shall be classed as No. 1 Rails.

No. 2 Rails. 19. (*a*) Rails which are rough on the head or which by reason of surface or other imperfections are not classed as No. 1 rails, shall be classed as No. 2 rails; provided they do not, in the judgment of the inspector, contain imperfections in such number and of such character as to render them unfit for No. 2 rail uses, and provided they conform to the requirements specified in Section 11.

(*b*) Rails which have flaws in the head exceeding $\frac{1}{4}$ in. in depth, or in the base exceeding $\frac{1}{2}$ in. in depth, shall not be classed as No. 2 rails.

(*c*) No. 2 rails will be accepted to the extent of 10 per cent by weight of the entire order.

VII. MARKING AND LOADING.

Marking.

20. (*a*) The name or brand of the manufacturer, the year and month of manufacture, the letters "O. H.," the weight of the rail, and the section number, shall be legibly rolled in raised letters and figures on the web. The melt number shall be legibly stamped on each rail where it will not be covered subsequently by the joint plates.

(*b*) Both ends of all short-length No. 1 rails shall be painted green.

Both ends of all No. 2 rails shall be painted white and shall have two heavy center-punch marks on the web at each end at such a distance from the end that they will not be covered subsequently by the joint plates.

Loading.

21. (*a*) Rails shall be loaded in the presence of the inspector, and shall be handled in such a manner as not to bruise the flanges or cause other injuries.

(*b*) Rails of each class shall be placed together in loading.

(*c*) Rails shall be paired as to length before shipment.

VIII. INSPECTION.

Inspection.

22. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BRIDGES.

Serial Designation: A 7 – 16.

The specifications for this material are issued under the fixed designation A 7; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1909, 1913, 1914, 1915, 1916.

Steel Castings.

1. The Standard Specifications for Steel Castings (Serial Designation: A 27), adopted by the American Society for Testing Materials, shall govern the purchase of steel castings for bridges. Unless otherwise specified, Class B castings, medium grade, shall be used.

I. MANUFACTURE.

Process.

2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

		Structural Steel.	Rivet Steel.
Phosphorus	Acid	not over 0.06	not over 0.04 per cent
	Basic	" " 0.04	" " 0.04 "
Sulfur		" " 0.05	" " 0.045 "

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered.	Structural Steel.	Rivet Steel.
Tensile strength, lb. per sq. in.	55 000 – 65 000[a]	46 000 – 56 000
Yield point, min., " "	0.5 tens. str.	0.5 tens. str
Elongation in 8 in., min., per cent.	$\frac{1\,500\,000[b]}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$
Elongation in 2 in., " "	22	.....

[a] See Paragraph (*b*).
[b] See Section 7.

(*b*) In order to meet the required minimum tensile strength of full-size annealed eyebars, the purchaser may determine the tensile strength to be obtained in specimen tests; the range shall not exceed 14,000 lb. per sq. in., and the maximum shall not exceed 74,000 lb. per sq. in. The material shall conform to the requirements as to physical properties other than that of tensile strength, specified in Sections 6, 7 and 8(*b*).

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. (*a*) For structural steel over $\frac{3}{4}$ in. in thickness, a deduction of 1 from the percentage of elongation in 8 in. specified in Section 6 (*a*) shall be made for each increase of $\frac{1}{8}$ in. in thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For structural steel under $\frac{5}{16}$ in. in thickness, a deduction of 2.5 from the percentage of elongation in 8 in. specified in Section 6 (*a*) shall be made for each decrease of $\frac{1}{16}$ in. in thickness below $\frac{5}{16}$ in.

Bend Tests.

8. (*a*) The test specimen for plates, shapes, and bars, except as specified in Paragraphs (*b*), (*c*) and (*d*), shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thick

ness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for eyebar flats shall bend cold through 180 deg. without cracking on the outside of the bent portion as follows: For material $\frac{3}{4}$ in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

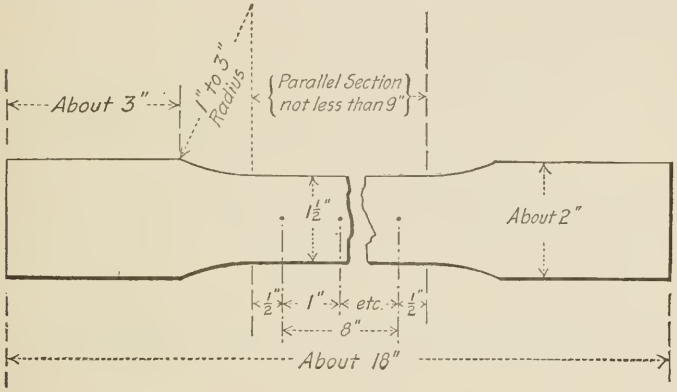


FIG. 1.

(*c*) The test specimen for pins, rollers and other bars when prepared as specified in Section 9 (*e*), shall bend cold through 180 deg. around a 1-in. pin without cracking on the outside of the bent portion.

(*d*) The test specimen for rivet steel shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens.

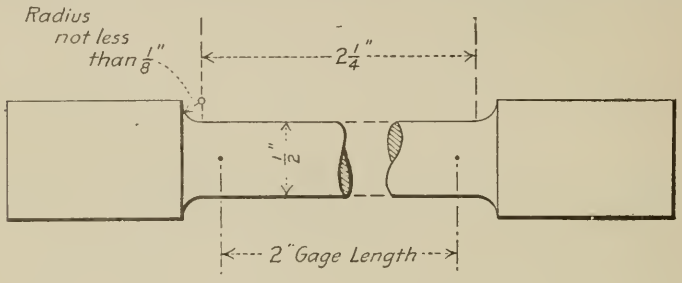
9. (*a*) Tension and bend test specimens shall be taken from rolled steel in the condition in which it comes from the rolls, except as specified in Paragraph (*b*).

(*b*) Tension and bend test specimens for pins and rollers shall be taken from the finished bars, after annealing when annealing is specified.

(*c*) Tension and bend test specimens for plates, shapes and bars, except as specified in Paragraphs (*d*), (*e*) and (*f*), shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel; except that bend test specimens for eyebars flats may have three rolled sides.

(*d*) Tension and bend test specimens for plates, and tension test specimens for eyebar flats, over $1\frac{1}{2}$ in. in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*e*) Tension test specimens for pins, rollers and bars (except eyebar flats) over $1\frac{1}{2}$ in. in thickness or diameter may conform to



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

the dimensions shown in Fig. 2. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by $\frac{1}{2}$ in. in section. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the bar.

(*f*) Tension and bend test specimens for rivet steel shall be of the full-size section of bars as rolled.

Number of Tests

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6(*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

11. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1½ times the amount given in this table.

[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table II.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

V. FINISH.

Finish. 12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 13. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

[1] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

VII. INSPECTION AND REJECTION.

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

STRUCTURAL NICKEL STEEL.

Serial Designation: A 8 – 16.

The specifications for this material are issued under the fixed designation A 8; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1916.

I. MANUFACTURE.

Process.

1. The steel shall be made by the open-hearth process.

Discard.

2. A sufficient discard shall be made from each ingot intended for eyebars to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

	Structural Steel.	Rivet Steel.
Carbon	not over 0.45	not over 0.30 per cent
Manganese	" " 0.70	" " 0.60 "
Phosphorus, Acid	" " 0.05	" " 0.04 "
Phosphorus, Basic	" " 0.04	" " 0.03 "
Sulfur	" " 0.05	" " 0.045 "
Nickel	not under 3.25	not under 3.25 "

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test

ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. Analyses may be made by the purchaser from finished material representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered.	Rivet Steel.	Plates, Shapes and Bars.	Eye Bars and Rollers,[c] Unannealed.	Eye Bars[a] and Pins,[c] Annealed.
Tensile strength, lb. per sq. in.	70 000 – 80 000	85 000 – 100 000	95 000 – 110 000	90 000 – 105 000
Yield point, min., lb. per sq. in.	45 000	50 000	55 000	52 000
Elongation in 8 in., min., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$[b]	$\frac{1\,500\,000}{\text{Tens. str.}}$[b]	20
Elongation in 2 in., min., per cent	.....	.....	16	20
Reduction of area, min., per cent	40	25	25	35

[a] Tests of annealed specimens of eye bars shall be made for information only.
[b] See Section 7.
[c] Elongation shall be measured in 2 in.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. For plates, shapes, and unannealed bars over 1 in. in thickness, a deduction of 1 from the percentage of elongation specified in Section 6 (*a*) shall be made for each increase of $\frac{1}{8}$ in. in thickness above 1 in., to a minimum of 14 per cent.

Character of Fracture.

8. All broken tension test specimens shall show either a silky or a very fine granular fracture, of uniform color, and free from coarse crystals.

Bend Tests.

9. (*a*) The test specimen for plates, shapes and bars shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, around a pin the diameter of which is equal to the

thickness of the specimen; and for material over $\frac{3}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for pins and rollers shall bend cold through 180 deg. around a 1-in. pin without cracking on the outside of the bent portion.

(*c*) The test specimen for rivet steel shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Drift Tests.

10. Punched rivet holes pitched two diameters from a planed edge shall stand drifting until the diameter is enlarged 50 per cent, without cracking the metal.

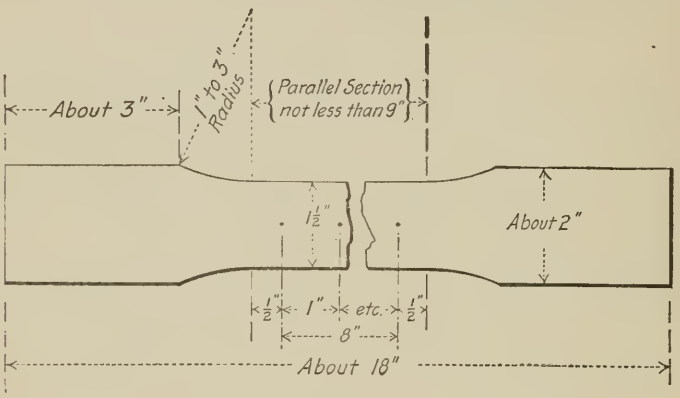


FIG. 1.

Test Specimens

11. (*a*) Tension and bend test specimens shall be taken from the finished material. Specimens for pins shall be taken after annealing.

(*b*) Tension and bend test specimens for plates, shapes and bars, except as specified in Paragraph (*c*), shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel; except that bend test specimens shall not be less than 2 in. in width, and that bend test specimens for eyebar flats may have three rolled sides.

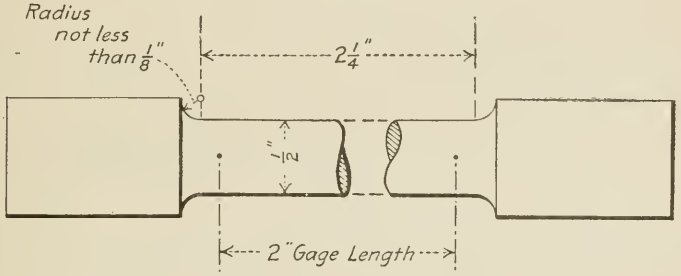
(*c*) Tension and bend test specimens for plates and bars (except eyebar flats) over $1\frac{1}{2}$ in. in thickness or diameter may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*d*) The axis of tension and bend test specimens for pins and rollers shall be 1 in. from the surface and parallel to the axis of the bar. Tension test specimens shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be 1 by $\frac{1}{2}$ in. in section.

(*e*) Tension and bend test specimens for rivet steel shall be of the full-size section of bars as rolled.

Number of Tests.

12. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

13. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5.	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1½ times the amount given in this table.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

[2] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

V. FINISH.

Finish. 14. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 15. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection. 16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all

reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

18. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

VIII. FULL-SIZE TESTS.

Tests of Eyebars.

19. (*a*) Full-size tests of annealed eyebars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.....	85 000–100 000
Yield point, min., " "	48 000
Elongation in 18 ft., min., per cent.....	10
Reduction of area, " "	30

(*b*) The yield point shall be determined by the halt of the gage of the testing machine.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

STRUCTURAL STEEL FOR BUILDINGS.

Serial Designation: A 9 – 16.

The specifications for this material are issued under the fixed designation A 9; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1916.

I. MANUFACTURE.

Process.

1. (*a*) Structural steel, except as noted in Paragraph (*b*), may be made by the Bessemer or the open-hearth process.

(*b*) Rivet steel, and steel for plates or angles over $\frac{3}{4}$ in. in thickness which are to be punched, shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

2. The steel shall conform to the following requirements as to chemical composition:

		Structural Steel.	Rivet Steel.
Phosphorus	Bessemer	not over 0.10 per cent	.....
	Open-hearth	" " 0.06 "	not over 0.06 per cent
Sulfur		....	" " 0.045 "

Ladle Analyses.

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The

chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

Check Analyses.

4. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 2 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS

Tension Tests.

5. (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered.	Structural Steel.	Rivet Steel.
Tensile strength, lb. per sq. in.	55 000 - 65 000	46 000 - 56 000
Yield point, min., " "	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent.	$\frac{1\,400\,000}{\text{Tens. str.}}$[a]	$\frac{1\,400\,000}{\text{Tens. str.}}$
Elongation in 2 in. " "	22	.....

[a] See Section 6.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

6. (*a*) For structural steel over $\frac{3}{4}$ in. in thickness, a deduction of 1 from the percentage of elongation in 8 in. specified in Section 5(*a*) shall be made for each increase of $\frac{1}{8}$ in. in thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For structural steel under $\frac{5}{16}$ in. in thickness, a deduction of 2.5 from the percentage of elongation in 8 in. specified in Section 5(*a*) shall be made for each decrease of $\frac{1}{16}$ in. in thickness below $\frac{5}{16}$ in.

Bend Tests.

7. (*a*) The test specimen for plates, shapes and bars, except as specified in Paragraphs (*b*) and (*c*), shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for pins, rollers and other bars, when prepared as specified in Section 8(*e*), shall bend cold through 180 deg. around a 1-in. pin without cracking on the outside of the bent portion.

(*c*) The test specimen for rivet steel shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens.

8. (*a*) Tension and bend test specimens shall be taken from rolled steel in the condition in which it comes from the rolls, except as specified in Paragraph (*b*).

(*b*) Tension and bend test specimens for pins and rollers shall be taken from the finished bars, after annealing when annealing is specified.

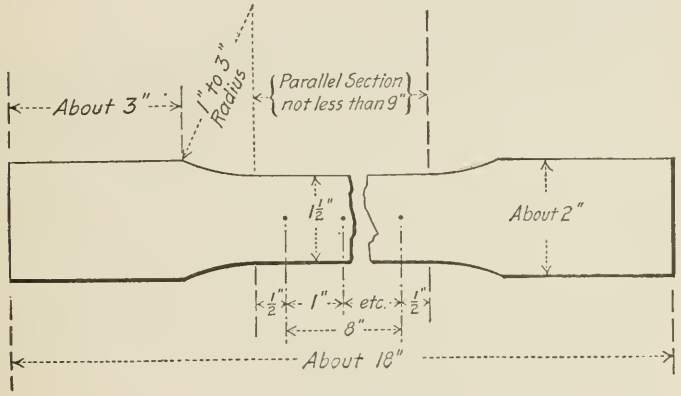


FIG. 1.

(*c*) Tension and bend test specimens for plates, shapes and bars, except as specified in Paragraphs (*d*), (*e*) and (*f*), shall be of the full thickness of material as rolled; and may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Tension and bend test specimens for plates over 1½ in. in thickness may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

(*e*) Tension test specimens for pins, rollers and bars over 1½ in. in thickness or diameter may conform to the dimensions shown in Fig. 2. In this case, the ends shall be of a form to

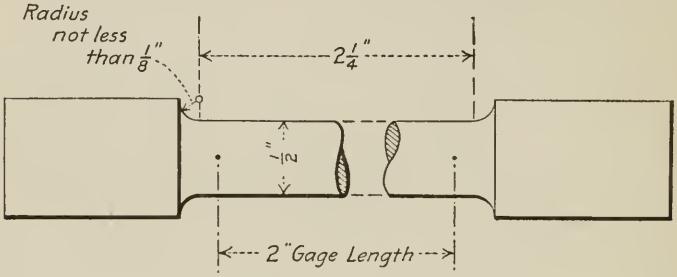
fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by $\frac{1}{2}$ in. in section. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the bar.

(*f*) Tension and bend test specimens for rivet steel shall be of the full-size section of bars as rolled.

Number of Tests.

9. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

10. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in

the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{2}$ times the amount given in this table.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

[2] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

V. FINISH.

Finish. 11. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 12. The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection. 13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being

furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

15. Samples tested in accordance with Section 4, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

BILLET-STEEL CONCRETE REINFORCEMENT BARS.

Serial Designation: A 15 – 14.

The specifications for this material are issued under the fixed designation A 15; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1913, 1914.

Classes.

1. (*a*) These specifications cover three classes of billet-steel concrete reinforcement bars, namely: plain, deformed, and cold-twisted.

(*b*) Plain and deformed bars are of three grades, namely: structural-steel, intermediate and hard.

Basis of Purchase.

2. (*a*) The structural-steel grade shall be used unless otherwise specified.

(*b*) If desired, cold-twisted bars may be purchased on the basis of tests of the hot-rolled bars before twisting, in which case such tests shall govern and shall conform to the requirements specified for plain bars of structural-steel grade.

I. MANUFACTURE.

Process.

3. (*a*) The steel may be made by the Bessemer or open-hearth process.

(*b*) The bars shall be rolled from new billets. No rerolled material will be accepted.

Cold-twisted Bars.

4. Cold-twisted bars shall be twisted cold with one complete twist in a length not over 12 times the thickness of the bar.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

5. The steel shall conform to the following requirements as to chemical composition:

Phosphorus { Bessemer .....not over 0.10 per cent
Open-hearth..... " " 0.05 "

Ladle Analyses.

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 5.

Check Analyses.

7. Analyses may be made by the purchaser from finished bars representing each melt of open-hearth steel, and each melt, or lot of ten tons, of Bessemer steel. The phosphorus content thus determined shall not exceed that specified in Section 5 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

8. (*a*) The bars shall conform to the following requirements as to tensile properties:

TENSILE PROPERTIES.

Properties Considered.	Plain Bars.			Deformed Bars.			Cold-twisted Bars.
	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	
Tensile strength, lb. per sq. in.....	55 000 to 70 000	70 000 to 85 000	80 000 min.	55 000 to 70 000	70 000 to 85 000	80 000 min.	Recorded only.
Yield point, min., lb. per sq. in.....	33 000	40 000	50 000	33 000	40 000	50 000	55 000
Elongation in 8 in., min., per cent.....	1 400 000[a] / Tens. str.	1 300 000[a] / Tens. str.	1 200 000[a] / Tens. str.	1 250 000[a] / Tens. str.	1 125 000[a] / Tens. str.	1 000 000[a] / Tens. str.	5

[a] See Section 9.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

9. (*a*) For plain and deformed bars over $\frac{3}{4}$ in. in thickness or diameter, a deduction of 1 from the percentages of elongation

specified in Section 8 (*a*) shall be made for each increase of $\frac{1}{8}$ in. in thickness or diameter above $\frac{3}{4}$ in.

(*b*) For plain and deformed bars under $\frac{7}{16}$ in. in thickness or diameter, a deduction of 1 from the percentages of elongation specified in Section 8 (*a*) shall be made for each decrease of $\frac{1}{16}$ in. in thickness or diameter below $\frac{7}{16}$ in.

Bend Tests

10. The test specimen shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

BEND-TEST REQUIREMENTS.

Thickness or Diameter of Bar.	Plain Bars.			Deformed Bars.			Cold-twisted Bars.
	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	Structural-Steel Grade.	Intermediate Grade.	Hard Grade.	
Under $\frac{3}{4}$ in.....	180 deg. d=t	180 deg. d=2t	180 deg. d=3t	180 deg. d=t	180 deg. d=3t	180 deg. d=4t	180 deg. d=2t
$\frac{3}{4}$ in. or over.....	180 deg. d=t	90 deg. d=2t	90 deg. d=3t	180 deg. d=2t	90 deg. d=3t	90 deg. d=4t	180 deg. d=3t

EXPLANATORY NOTE: d=the diameter of pin about which the specimen is bent; t=the thickness or diameter of the specimen.

Test Specimens

11. (*a*) Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 in., if deemed necessary by the manufacturer to obtain uniform cross-section.

(*b*) Tension and bend test specimens for cold-twisted bars shall be taken from the finished bars, without further treatment; except as specified in Section 2 (*b*).

Number of Tests.

12. (*a*) One tension and one bend test shall be made from each melt of open-hearth steel, and from each melt, or lot of ten tons, of Bessemer steel; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness or diameter, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 8 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT.

Permissible Variations.

13. The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.

V. FINISH.

Finish.

14. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI. INSPECTION AND REJECTION.

Inspection.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 7 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

17. Samples tested in accordance with Section 7, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

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STANDARD SPECIFICATIONS

FOR

RAIL-STEEL CONCRETE REINFORCEMENT BARS.

Serial Designation: A 16 – 14.

The specifications for this material are issued under the fixed designation A 16; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914.

Classes. 1. These specifications cover three classes of rail-steel concrete reinforcement bars, namely: plain, deformed, and hot-twisted.

I. MANUFACTURE.

Process. 2. The bars shall be rolled from standard section Tee rails.

Hot-twisted Bars. 3. Hot-twisted bars shall have one complete twist in a length not over 12 times the thickness of the bar.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 4. (*a*) The bars shall conform to the following minimum requirements as to tensile properties:

Properties Considered.	Plain Bars.	Deformed and Hot-twisted bars.
Tensile strength, lb. per sq. in.	80 000	80 000
Yield point, lb. per sq. in.	50 000	50 000
Elongation in 8 in., per cent[1]	$\frac{1\,200\,000}{\text{Tens. str.}}$	$\frac{1\,000\,000}{\text{Tens. str.}}$

[1] See Section 5.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

5. (*a*) For bars over $\frac{3}{4}$ in. in thickness or diameter, a deduction of 1 from the percentages of elongation specified in Section 4 (*a*) shall be made for each increase of $\frac{1}{8}$ in. in thickness or diameter above $\frac{3}{4}$ in.

(*b*) For bars under $\frac{7}{16}$ in. in thickness or diameter, a deduction of 1 from the percentages of elongation specified in Section 4 (*a*) shall be made for each decrease of $\frac{1}{16}$ in. in thickness or diameter below $\frac{7}{16}$ in.

Bend Tests.

6. The test specimen shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

Thickness or Diameter of Bar.	Plain Bars.	Deformed and Hot-twisted Bars.
Under $\frac{3}{4}$ in.	180 deg. d = 3 t	180 deg. d = 4 t
$\frac{3}{4}$ in. or over	90 deg. d = 3 t	90 deg. d = 4 t

EXPLANATORY NOTE: d = the diameter of pin about which the specimen is bent; t = the thickness or diameter of the specimen.

Test Specimens.

7. (*a*) Tension and bend test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 in., if deemed necessary by the manufacturer to obtain uniform cross-section.

(*b*) Tension and bend test specimens for hot-twisted bars shall be taken from the finished bars, without further treatment.

Number of Tests.

8. (*a*) One tension and one bend test shall be made from each lot of ten tons or less of each size of bar rolled from rails varying not more than 10 lb. per yd. in nominal weight.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 4 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

III. PERMISSIBLE VARIATIONS IN WEIGHT.

Permissible Variations.

9. The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.

IV. FINISH.

Finish.

10. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

V. INSPECTION AND REJECTION.

Inspection.

11. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

12. Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

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STANDARD SPECIFICATIONS

FOR

CARBON-STEEL AND ALLOY-STEEL FORGINGS.

Serial Designation: A 18 – 16.

The specifications for this material are issued under the fixed designation A 18; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1914, 1916.

Classes.

1. (*a*) These specifications cover the various classes of carbon-steel and alloy-steel forgings now commonly used and not covered by other existing specifications of the American Society for Testing Materials.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for forgings which may be welded or case-hardened;

Class B, for mild-steel forgings for structural purposes, for minor ship fittings, etc.;

Class C, for mild-steel forgings for structural purposes, for ships, etc.;

Classes D, E, F, G, H and I, for various machinery forgings, choice depending upon design and upon the stresses and services to be imposed.

Classes K, L and M, for various machinery forgings, choice depending upon design and upon the stresses and services to be imposed, and upon the character of machining operations to be done.

I. MANUFACTURE.

Process.

2. The steel may be made by the open-hearth or any other process approved by the purchaser.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests.

4. The manufacturer and the purchaser shall agree upon forgings on which a prolongation for test purposes shall be provided.

Boring.

5. If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

Heat Treatment.

6. Heat treatment, if required, shall consist of either annealing or quenching and tempering, as specified.

(*a*) For annealing, the forgings shall be allowed to become cold after forging. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly.

(*b*) For quenching and tempering, the forgings shall be allowed to become cold after forging. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

7. (*a*) The steel shall conform to the following requirements as to chemical composition:

Elements Considered.	Classes.				
	A.	B, C, D, E, F, G.	H, I.	K, L.	M.
Manganese, per cent....	0.30 – 0.55	0.40 – 0.80	0.40 – 0.80	.....	.....
Phosphorus, per cent:					
Acid.....	not over 0.05	not over 0.05	not over 0.04	not over 0.05	not over 0.04
Basic.....	" " 0.05	" " 0.05	" " 0.04	" " 0.04	" " 0.04
Sulfur, per cent.....	" " 0.05	" " 0.05	" " 0.05	" " 0.05	" " 0.05
Nickel, per cent.....	.....	.....	not under 3.00	.....	.....

(*b*) The composition of alloy steel, other than phosphorus and sulfur, to be used in forgings of classes K, L and M, shall be agreed upon by the manufacturer and the purchaser.[1]

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese and the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

10. (*a*) The forgings shall conform to the requirements as to tensile properties specified in Tables I, II and III.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

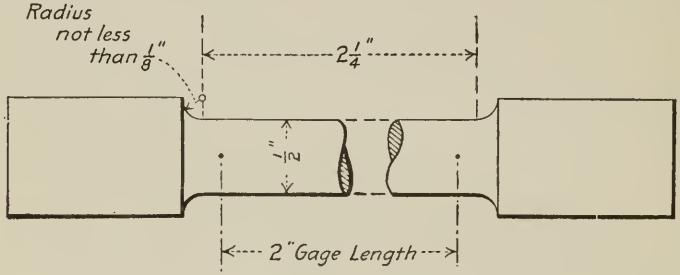
(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

[1] The question of chemical composition of the several types of alloy steels is not yet sufficiently standardized to warrant the inclusion of formal requirements covering chemical composition of such alloy steels in standard specifications.

The following compositions are quoted as being as nearly typical as any now regularly manufactured:

Elements Considered.	Chrome-Vanadium Steel.		Chrome-Nickel Steel.		Chromium Steel.
	Classes K and L.	Class M.	Classes K and L.	Class M.	Classes K and L.
Carbon, per cent.....	0.28 – 0.42	0.35 – 0.50	0.28 – 0.42	0.35 – 0.50	0.28 – 0.42
Manganese, per cent....	0.40 – 0.70	0.50 – 0.90	0.40 – 0.70	0.50 – 0.90	0.40 – 0.70
Chromium, per cent....	0.75 – 1.25	0.75 – 1.25	not under 0.70	not under 0.70	0.60 – 0.90
Vanadium, per cent.....	not under 0.15	not under 0.15	.....	.....	.....
Nickel, per cent.....	.....	.....	not under 1.25	not under 2.75	.....

(*d*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*e*) Tests of forgings shall be made only after final treatment.

Tension Test Specimens.

11. (*a*) Tension test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) The specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

TABLE I.—TENSILE PROPERTIES (CLASSES A TO F, INCLUSIVE).

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 IN.

CLASS.	SIZE. Outside Diameter or Over-all Thickness.	Tensile Strength, min. (except Class A), lb. per sq. in.	Yield Point, min., lb. per sq. in.	Elongation in 2 in., min., per cent.		Reduction of Area, min., per cent.	
				Inverse Ratio.	Not under	Inverse Ratio.	Not under
A UNTREATED	All sizes.....	47 000 to 60 000	0.5 tens. str.	1 500 000 / Tens. str.	..	2 500 000 / Tens. str.	..
B UNTREATED	Not over 12 in..	60 000	0.5 tens. str.	1 550 000 / Tens. str.	22	2 400 000 / Tens. str.	35
	Over 12 to 20 in., inclusive..	60 000	0.5 tens. str	1 480 000 / Tens. str.	21	2 220 000 / Tens. str.	32
C ANNEALED	Not over 12 in..	60 000	0.5 tens. str.	1 700 000 / Tens. str.	25	2 700 000 / Tens. str.	38
	Over 12 to 20 in., inclusive..	60 000	0.5 tens. str.	1 600 000 / Tens. str.	24	2 520 000 / Tens. str.	36
D UNTREATED	Not over 8 in...	75 000	0.5 tens. str.	1 600 000 / Tens. str.	18	2 200 000 / Tens. str.	24
	Over 8 to 12 in., inclusive.....	75 000	0.5 tens. str.	1 500 000 / Tens. str.	17	2 000 000 / Tens. str.	22
	Over 12 to 20 in., inclusive..	75 000	0.5 tens. str.	1 400 000 / Tens. str.	16	1 800 000 / Tens. str.	20
E ANNEALED	Not over 8 in...	75 000	0.5 tens. str.	1 800 000 / Tens. str.	20	2 800 000 / Tens. str.	33
	Over 8 to 12 in., inclusive	75 000	0.5 tens. str.	1 725 000 / Tens. str.	19	2 640 000 / Tens. str.	31
	Over 12 to 20 in., inclusive..	75 000	0.5 tens. str.	1 650 000 / Tens. str.	18	2 400 000 / Tens. str.	29
F ANNEALED	Not over 8 in...	80 000	0.5 tens. str.	1 800 000 / Tens. str.	20	2 800 000 / Tens. str.	32
	Over 8 to 12 in., inclusive.....	80 000	0.5 tens. str.	1 725 000 / Tens. str.	19	2 640 000 / Tens. str.	30
	Over 12 to 20 in., inclusive..	80 000	0.5 tens. str.	1 650 000 / Tens. str.	18	2 400 000 / Tens. str.	28

12. Unless otherwise specified by the purchaser, tests shall be made as follows: **Number of Tests.**

(*a*) For untreated forgings, one tension test shall be made from each melt.

TABLE II.—TENSILE PROPERTIES (CLASSES G, H, AND I).

CLASS.	SIZE.	Tensile Strength, min., lb. per sq. in.	Elastic Limit, min., lb. per sq. in.	Elongation in 2 in., min., per cent.		Reduction of Area, min., per cent.	
				Inverse Ratio.	Not under	Inverse Ratio.	Not under
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.							
G QUENCHED AND TEMPERED.	Up to 4 in. in outside diameter or thickness, 2-in. max. wall.....	90 000	55 000	2 100 000 / Tens. str.	20.5	4 000 000 / Tens. str.	39
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall.....	85 000	50 000	2 000 000 / Tens. str.	20.5	3 800 000 / Tens. str.	39
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall.....	85 000	50 000	1 900 000 / Tens. str.	19.5	3 600 000 / Tens. str.	37
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall.....	82 500	48 000	1 800 000 / Tens. str.	19	3 400 000 / Tens. str.	36
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 IN.							
H NICKEL STEEL, ANNEALED.	Outside diameter or over-all thickness not over 12 in.....	80 000	50 000	2 000 000 / Tens. str.	22	3 600 000 / Tens. str.	40
	Outside diameter or over-all thickness over 12 to 20 in., inclusive.....	80 000	50 000	1 900 000 / Tens. str.	21	3 400 000 / Tens. str.	38
FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.							
I NICKEL STEEL, QUENCHED AND TEMPERED.	Up to 4 in. in outside diameter or thickness, 2-in. max. wall.....	100 000	70 000	2 200 000 / Tens. str.	20	4 500 000 / Tens. str.	41
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall.....	100 000	65 000	2 100 000 / Tens. str.	20	4 300 000 / Tens. str.	41
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall.....	90 000	60 000	2 000 000 / Tens. str.	20	4 100 000 / Tens. str.	41
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall.....	85 000	55 000	1 900 000 / Tens. str.	20	3 900 000 / Tens. str.	41

TABLE III.—TENSILE PROPERTIES (CLASSES K, L AND M).

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.

CLASS.	SIZE.	Tensile Strength, lb. per sq. in.	Elastic Limit, min., lb. per sq. in.	Elongation in 2 in., min., per cent.	Reduction of Area, min., per cent.
K ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 in. in outside diameter or thickness, 1-in. max. wall....	95 000 – 115 000	70 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	90 000 – 110 000	65 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall.....	90 000 – 110 000	65 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall.....	90 000 – 110 000	65 000	20	50
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	85 000 – 105 000	60 000	20	50
L ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 in. in outside diameter or thickness, 1-in. max. wall..	105 000 – 125 000	80 000	20	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	100 000 – 120 000	75 000	20	50
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall.....	100 000 – 120 000	75 000	20	50
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall.....	100 000 – 120 000	75 000	18	45
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	95 000 – 115 000	70 000	18	45
		Minimum.			
M ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 in. in outside diameter or thickness, 1-in. max. wall.	125 000	105 000	16	50
	Over 2 to 4 in. in outside diameter or thickness, 2-in. max. wall	115 000	95 000	16	45
	Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall.....	110 000	85 000	16	45
	Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall.....	100 000	75 000	18	45
	Outside diameter or thickness not over 20 in., 5 to 8-in. wall	100 000	70 000	18	45

(*b*) For annealed forgings, one tension test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension test shall be made from each melt.

(*c*) For quenched and tempered forgings, one tension test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension test shall be made from each melt.

(*d*) If more than one class of forgings by size is represented in any lot, one tension test from a forging of each class by size shall be made as specified in Sections 10 and 11.

(*e*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*f*) If the percentage of elongation of any test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests.

13. (*a*) If the results of the physical tests of any test lot of forgings in classes A to I, inclusive, do not conform to the requirements specified, the manufacturer may re-treat such lot one or more times and retests shall be made as specified in Section 12.

(*b*) If the results of the physical tests of any test lot of forgings in classes K, L or M do not conform to the requirements specified, the manufacturer may retemper or requench and temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 12.

IV. WORKMANSHIP AND FINISH.

Workmanship.

14. The forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish.

15. The forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

16. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks. Marking.

VI. INSPECTION AND REJECTION.

17. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment. Inspection.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

18. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 17 (*b*) shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

19. Samples tested in accordance with Section 17 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

QUENCHED-AND-TEMPERED CARBON-STEEL AXLES' SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS.

Serial Designation: A 19 – 16.

The specifications for this material are issued under the fixed designation A 19; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1914, 1916.

Basis of Purchase.

1. When used for forgings for locomotives, these specifications cover quenched-and-tempered carbon-steel driving axles, engine and trailing-truck axles, main and side rods, straps, crank pins and piston rods.

I. MANUFACTURE.

Process.

2. The steel may be made by the open-hearth or any other process approved by the purchaser.

Discard.

3. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Prolongations for Tests.

4. For test purposes, a prolongation shall be left on each forging, unless otherwise specified by the purchaser.

Boring.

5. (*a*) Unless otherwise specified by the purchaser, all forgings over 7 in. in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring and rough turning shall be done before quenching.

(*b*) If boring is specified, the diameter of the hole shall

be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

Heat Treatment.

6. For quenching and tempering, the forgings shall be allowed to become cold after forging. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

7. The steel shall conform to the following requirements as to chemical composition:

Carbon	First Class by Size	0.25 – 0.60 per cent
	Second " " "	0.35 – 0.60 "
	Third " " "	0.35 – 0.65 "
	Fourth " " "	0.35 – 0.70 "
Manganese		0.40 – 0.70 "
Phosphorus		not over 0.05 "
Sulfur		" " 0.05 "

Ladle Analyses.

8. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 7.

Check Analyses.

9. (*a*) An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

(*b*) In addition to the complete analysis specified in Paragraph (*a*), a phosphorus determination may be made by the

purchaser from each broken tension test specimen. The phosphorus content thus determined shall conform to the requirement specified in Section 7.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

10. (*a*) The forgings shall conform to the minimum requirements as to tensile properties specified in Table I.

TABLE I.—TENSILE PROPERTIES.

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 IN. WHEN SOLID, AND NOT OVER 20 IN. WHEN BORED.

SIZE.	Tensile Strength, lb. per sq. in.	Elastic Limit, lb. per sq. in.	Elongation in 2 in., per cent.		Reduction of Area, per cent.	
			Inverse Ratio.	Not under	Inverse Ratio.	Not under
Up to 4 in. in outside diameter or thickness, 2-in. max. wall.....	90 000	55 000	$\frac{2\,100\,000}{\text{Tens. str.}}$	20.5	$\frac{4\,000\,000}{\text{Tens. str.}}$	39
Over 4 to 7 in. in outside diameter or thickness, 3½-in. max. wall.....	85 000	50 000	$\frac{2\,000\,000}{\text{Tens. str.}}$	20.5	$\frac{3\,800\,000}{\text{Tens. str}}$	39
Over 7 to 10 in. in outside diameter or thickness, 5-in. max. wall.....	85 000	50 000	$\frac{1\,900\,000}{\text{Tens. str.}}$	19.5	$\frac{3\,600\,000}{\text{Tens. str.}}$	37
Outside diameter or thickness not over 20 in., 5 to 8-in. wall... .	82 500	48 000	$\frac{1\,800\,000}{\text{Tens. str.}}$	19	$\frac{3\,400\,000}{\text{Tens. str.}}$	36

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*d*) Tests of forgings shall be made only after final treatment.

11. If specified by the purchaser, bend tests shall be made as follows: Bend Tests.

(*a*) For the first and second classes by size, the test specimen shall bend cold through 180 deg. around a 1-in. flat mandrel having a rounded edge of $\frac{1}{2}$-in. radius, without cracking on the outside of the bent portion.

(*b*) For the third and fourth classes by size, the test specimen shall bend cold through 180 deg. around a $1\frac{1}{2}$-in. flat mandrel having a rounded edge of $\frac{3}{4}$-in. radius, without cracking on the outside of the bent portion.

12. Unless otherwise specified by the purchaser, all forgings shall be subjected to an impact proof test. The details of this test shall be agreed upon by the manufacturer and the purchaser.[1] Proof Tests.

13. (*a*) Tension and bend test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser. Test Specimens.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend test specimens shall be $\frac{1}{2}$ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

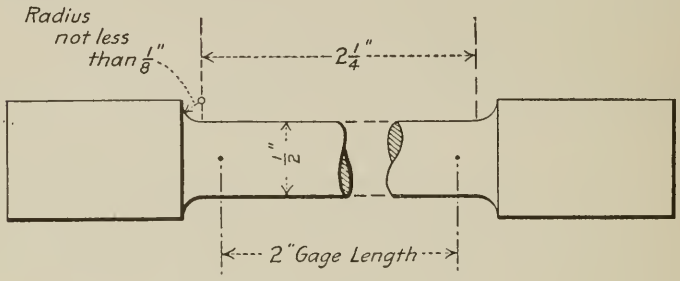
14. (*a*) One tension and, if specified by the purchaser, one bend test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension and, if specified, one bend test shall be Number of Tests.

[1] For information relative to proof tests of finished forgings, see Appendix, pp. 157–158.

made from each quenching charge. If more than one melt is represented in a quenching charge, one tension and, if specified, one bend test shall be made from each melt.

(*b*) If more than one class of forgings by size is represented in any lot, one tension and, if specified, one bend test from a forging of each class by size shall be made as specified in Sections 10, 11 and 13.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.



Note:—The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*d*) If the percentage of elongation of any tension test specimen is less than that specified in Section 10 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests. 15. (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retemper or requench and temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 14.

(*b*) If the fracture of any tension test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be

retempered or requenched and tempered. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

IV. WORKMANSHIP AND FINISH.

Workmanship. 16. The forgings shall conform to the sizes and shapes specified by the purchaser. Axles, shafts and similar forgings, unless otherwise specified, shall be rough-turned all over with an allowance of $\frac{1}{8}$ in. on the surface for finishing. In centering, 60-deg. centers with clearance drilled for points shall be used.

Finish. 17. The forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING.

Marking. 18. Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION.

Inspection. 19. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 19 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing. 21. Samples tested in accordance with Section 19 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

APPENDIX.

As a guide in determining a proof test for quenched-and-tempered forgings, the following particulars regarding three methods of proof testing now being used are given:[1]

The Pennsylvania Railroad Co. and the Standard Steel Works Co. require that axles, shafts and similar forgings shall

PROOF TESTS FOR QUENCHED-AND-TEMPERED FORGINGS.

Diameter, in.	PENNSYLVANIA RAILROAD CO.; STANDARD STEEL WORKS CO.		NEW YORK CENTRAL LINES; CARNEGIE STEEL CO.
	Height of Drop, ft. and in.		
	1640-lb. Tup.	2240-lb. Tup.	Energy of Blow, ft. lb.
$4\frac{1}{2}$	0 ft. 11 in.	.....	700
5	1 " 3 "	.....	900
$5\frac{1}{2}$	1 " 8 "	1 ft. 2 in.	1 200
6	2 " 2 "	1 " 7 "	1 700
$6\frac{1}{2}$	2 " 9 "	2 " 0 "	2 500
7	3 " 5 "	2 " 6 "	3 500
$7\frac{1}{2}$	4 " 3 "	3 " 1 "	4 700
8	5 " 1 "	3 " 8 "	6 000
$8\frac{1}{2}$	6 " 2 "	4 " 6 "	7 500
9	7 " 3 "	5 " 3 "	9 000
$9\frac{1}{2}$	8 " 7 "	6 " 3 "	10 000
10	10 " 0 "	7 " 4 "	11 000
$10\frac{1}{2}$	11 " 7 "	8 " 6 "	12 000
11	13 " 5 "	9 " 10 "	13 000
$11\frac{1}{2}$	15 " 3 "	11 " 1 "	14 000
12	17 " 4 "	12 " 8 "	15 000

receive an impact proof test on an M.C.B. drop-test machine, with supports 3 ft. apart, two blows being struck with a tup weighing 1640 or 2240 lb. The former company requires that

[1] For more detailed information concerning these methods of proof testing, see Report of Committee A-1 on Standard Specifications for Steel, Appendix IV. "Report on Proof Tests of Finished Forgings," *Proceedings*, Am. Soc. for Test. Mats., Vol. XIV, Part II, p. 120 (1914).

both blows be struck at the center of the forging, which is to be turned 90 deg. after the first blow. The other requires that the forging be supported at one end for the first blow and at the other end for the second blow; and that the forging be turned 180 deg. after the first blow. The requirements as to height of drop given in the accompanying table are derived from the following formulas:

For the 1640-lb. tup: $H = 0.01D^3$;
" " 2240 " " $H = 0.0073D^3$;

in which H is height of drop in feet and D is diameter of the forging at the center in inches.

The New York Central Lines and the Carnegie Steel Co. require that forgings shall be submitted to an impact proof test by having them supported at the ends and being struck in the center one blow by a tup delivering the number of foot-pounds shown in the accompanying table.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

COLD-ROLLED STEEL AXLES.

Serial Designation: A 22 – 16.

The specifications for this material are issued under the fixed designation A 22; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1914, 1916.

I. MANUFACTURE.

Process.

1. (*a*) The steel may be made by the open-hearth or any other process approved by the purchaser.

(*b*) The axles shall be cold-rolled to finished size from hot-rolled bars.

Discard.

2. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

Carbon	not over 0.40 per cent
Manganese	0.40 – 0.80 "
Phosphorus	not over 0.05 "
Sulfur	" " 0.05 "

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements

specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from an axle representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. Drillings for analysis may be taken from the axle or from a full-size prolongation of the same, at any point midway between the center and surface; or turnings may be taken from a test specimen.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The axles shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	70 000
Elastic limit, " "	60 000
Elongation in 2 in., per cent	18
Reduction of area, "	35

(*b*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

Bend Tests.

7. The test specimen shall bend cold through 180 deg. around a 1-in. pin or mandrel, without cracking on the outside of the bent portion.

Test Specimens.

8. (*a*) Tension and bend test specimens shall be taken from the full-size prolongation of the axle. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the axle.

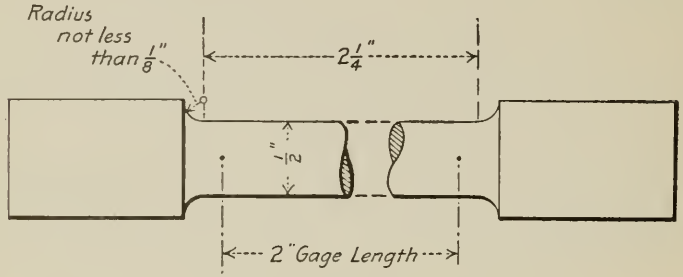
(*b*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*c*) Bend test specimens shall be $\frac{1}{2}$ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

Number of Tests.

9. (*a*) One tension and one bend test shall be made from each lot of 50 axles or less from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6(*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. WORKMANSHIP AND FINISH.

Workmanship.

10. The axles shall conform to the sizes and shapes specified by the purchaser, and shall not vary more than 0.002 in. from the diameter specified. When centered, 60-deg. centers with clearance drilled for points shall be used.

Finish.

11. The axles, either finished or plain, shall be straight and free from injurious defects, and shall have a workmanlike finish.

V. MARKING.

12. Identification marks shall be legibly stamped on each axle, and on each test specimen. The purchaser shall indicate the location of such identification marks. Marking.

VI. INSPECTION AND REJECTION.

13. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the axles ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the axles are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment. Inspection.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the axles in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 13 (*b*) shall be reported within five working days from the receipt of samples. Rejection.

(*b*) Axles which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

15. Samples tested in accordance with Section 13 (*b*), which represent rejected axles, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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STANDARD SPECIFICATIONS

FOR

WROUGHT SOLID CARBON-STEEL WHEELS FOR STEAM RAILWAY SERVICE.

Serial Designation: A 57 - 16.

The specifications for this material are issued under the fixed designation A 57; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1916.

I. MANUFACTURE.

Process. 1. The steel shall be made by the open-hearth process.

Discard. 2. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

	Acid.	Basic.	
Carbon	0.60 – 0.80	0.65 – 0.85	per cent
Manganese	0.55 – 0.80	0.55 – 0.80	"
Phosphorus	not over 0.05	not over 0.05	"
Sulfur	" " 0.05	" " 0.05	"
Silicon	0.15 – 0.35	0.10 – 0.30	"

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3. **Ladle Analyses.**

5. An analysis may be made by the purchaser from a wheel representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3. A sample may be taken from any one point in the plate; or two samples may be taken, in which case they shall be on radii at right angles to each other. Samples shall not be taken in such a way as to impair the usefulness of the wheel. Drillings for analysis shall be taken by boring entirely through the sample parallel to the axis of the wheel; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one wheel shall be thoroughly mixed together. **Check Analyses.**

III. MATING.

6. The wheels shall be mated as to tape sizes and shipped in pairs. **Mating.**

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS.[1]

7. The wheels shall conform to the dimensions specified within the following permissible variations: **Permissible Variations.**

FLANGE.

(*a*) *Height of Flange.*—The height of flange shall not be less, but may be $\frac{1}{8}$ in. more than that specified.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary more than $\frac{1}{16}$ in. from that specified.

(*c*) *Radius of Throat.*—The radius of throat shall not vary more than $\frac{1}{16}$ in. from that specified.

[1] To facilitate the use of the specifications, the various dimensions are illustrated in Fig. 1, and the permissible variations in those dimensions are also given in tabular form in Table I.

TABLE I.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF WROUGHT-STEEL WHEELS FOR STEAM RAILWAY SERVICE.

Dimensions.	Permissible Variations in Dimensions.	
	Over	Under
FLANGE.		
(*a*) Height	$\frac{1}{8}$ in.	0
(*b*) Thickness	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
(*c*) Radius of Throat	$\frac{1}{16}$ in.	$\frac{1}{16}$ in.
RIM.		
(*d*) Thickness, from Inner Edge to Intersection of Throat and Tread	.....	$\frac{3}{16}$ in.
(*e*) Width	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
(*f*) Maximum Departure of any Circle on Back Face from Plane	$\frac{1}{16}$ in.	
(*g*) Maximum Departure of Tread from Rotundity	$\frac{1}{16}$ in.	
(*h*) Maximum Height of Block Marks on Tread	$\frac{1}{64}$ in.	
(*i*) Tape Sizes	9	5
(*j*) Limit-of-Wear Groove:		
1. Maximum Departure from Specified Position	$\frac{1}{8}$ in.	
2. Minimum Distance from Inner Edge of Rim	$\frac{3}{4}$ in.	
PLATE.		
(*k*) Thickness, Variation for each $\frac{1}{8}$ in. of thickness	.....	$\frac{1}{32}$ in.
HUB.		
(*l*) 1. Diameter	.....	Limited by wall thickness.
2. Minimum Thickness of Wall, for Bore 7 in. or under	$1\frac{1}{8}$ in.	
3. Minimum Thickness of Wall, for Bore over 7 in	$1\frac{3}{8}$ in.	
4. Maximum Variation in Thickness of Wall in any One Wheel	$\frac{3}{8}$ in.	
(*m*) Length	$\frac{1}{8}$ in.	$\frac{1}{8}$ in.
(*n*) Depression below Front Face of Rim	$\frac{1}{8}$ in.	0
(*o*) Projection beyond Back Face of Rim	$\frac{1}{8}$ in.	0
BORE. (If not specified, Rough Bore shall be $\frac{1}{4}$ in. less than Finished Bore.)		
(*p*) Diameter of Rough Bore	$\frac{1}{16}$ in.	$\frac{1}{8}$ in.
(*q*) Maximum Depth of Black Spots in Rough Bore within 2 in. of End of Bore	$\frac{1}{16}$ in.	
(*r*) Maximum Eccentricity of Rough Bore in Relation to Tread	$\frac{3}{64}$ in.	

NOTE.—The letter used for each dimension in this table and in Fig. 1 is the same as that of the paragraph of Section 7 covering that dimension.

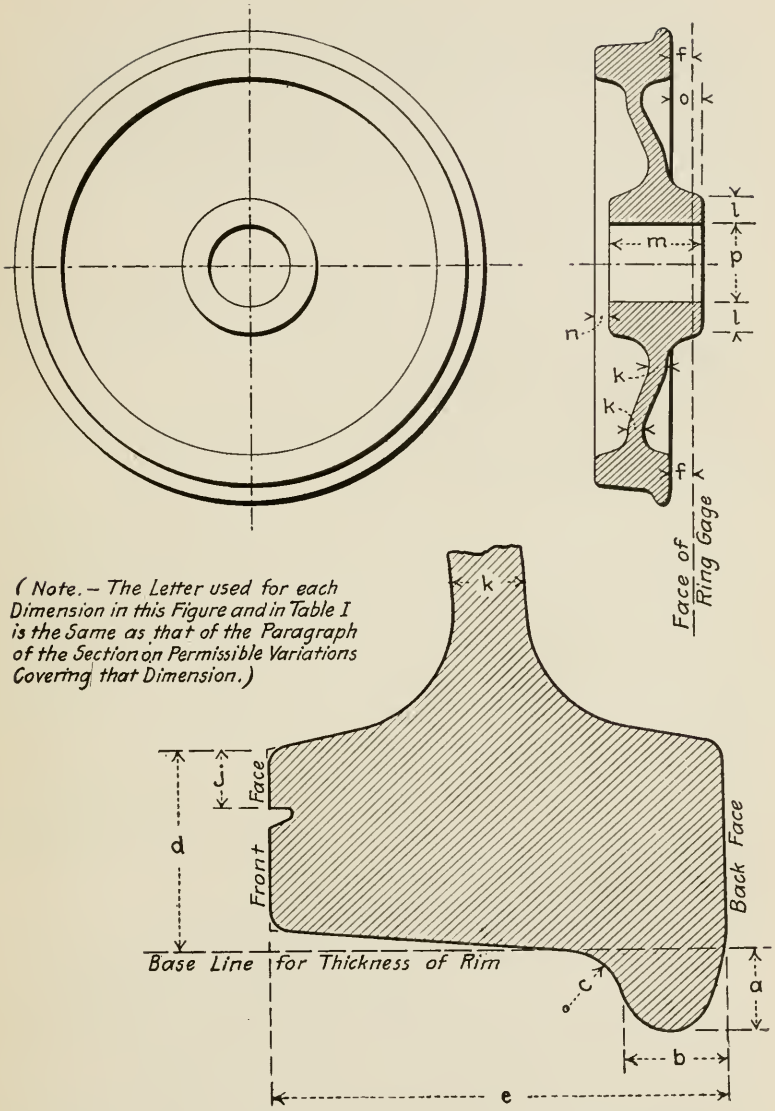


FIG. 1.—Diagram showing Points at which the Dimensions covered by the Specifications are Measured. For the Permissible Variations in these Dimensions see Table I or Section 7.

RIM.

(*d*) *Thickness of Rim.*—The rim may vary in thickness, but the variation less than that specified shall not exceed $\frac{3}{16}$ in. The thickness of rim shall be measured from the inner edge of the rim to a base line drawn from the intersection of the throat radius and the tread, parallel to the axis of the wheel.

(*e*) *Width of Rim.*—The width of rim shall not vary more than $\frac{1}{8}$ in. from that specified.

(*f*) *Plane.*—The wheels shall be gaged with a ring gage placed concentric with and perpendicular to the axis of the wheel. For all points on the back face of the rim equidistant from the center, the variation from the plane of the gage when so placed shall not exceed $\frac{1}{16}$ in.

(*g*) *Rotundity.*—The tread shall be gaged with a ring gage, and the opening between the tread and this gage at any point shall not exceed $\frac{1}{16}$ in.

(*h*) *Block Marks on Tread.*—Block marks shall not exceed $\frac{1}{64}$ in. in height.

(*i*) *Tape Sizes.*—The wheels shall not vary more than 9 tapes over nor more than 5 tapes under the size specified.

(*j*) *Limit-of-Wear Groove.*—When a limit-of-wear groove is specified, its location shall not vary more than $\frac{1}{8}$ in. from that specified, and its distance from the inner edge of the rim shall not at any point be less than $\frac{3}{4}$ in.

PLATE.

(*k*) *Thickness of Plate.*—The plate may vary in thickness, but the variation less than that specified shall not exceed $\frac{1}{32}$ in. for each $\frac{1}{8}$ in. in the thickness of the plate.

HUB.

(*l*) *Diameter of Hub.*—The diameter of hub may vary, but the thickness of wall of the finished bored hub shall not be less than $1\frac{1}{8}$ in. at any point for bores 7 in. or under in diameter, nor less than $1\frac{3}{8}$ in. for bores over 7 in. in diameter, unless otherwise specified. The thickness of wall of the hub shall not vary more than $\frac{3}{8}$ in. at any two points on the same wheel.

(*m*) *Length of Hub.*—The length of hub shall not vary more than $\frac{1}{8}$ in. from that specified.

(*n*) *Depression of Hub*.—For car and tender wheels and wheels of similar design, the depression of the hub below the front face of the rim shall not be less, but may be $\frac{1}{8}$ in. more than that specified.

(*o*) *Projection of Hub*.—For locomotive-truck wheels and wheels of similar design, the projection of the hub beyond the back face of the rim shall not be less, but may be $\frac{1}{8}$ in. more than that specified.

BORE.

(*p*) *Diameter of Rough Bore*.—The diameter of rough bore shall not vary more than $\frac{1}{16}$ in. over nor more than $\frac{1}{8}$ in. under that specified. When finished-bore diameter only is specified, the rough-bore diameter shall be made $\frac{1}{4}$ in. less with the permissible variations specified above.

(*q*) *Black Spots in Bore*.—Black spots in rough bore within 2 in. of either face of the hub shall not exceed $\frac{1}{16}$ in. in depth.

(*r*) *Eccentricity of Bore*.—The eccentricity between the tread at its center line and the rough bore shall not exceed $\frac{3}{64}$ in.

V. FINISH.

Finish. 8. (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheels shall not be offered for inspection if covered with paint, rust, or any other substance to such an extent as to hide defects.

VI. MARKING.

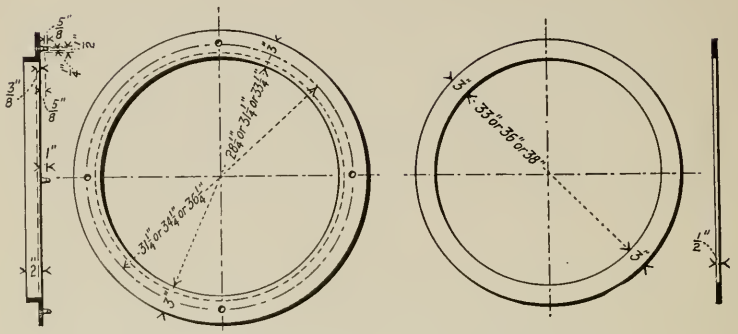
Marking. 9. (*a*) The name or brand of the manufacturer, date, and serial number shall be legibly stamped on each wheel in such a way that the wheel may be readily identified.

(*b*) The tape size shall be legibly marked on each wheel.

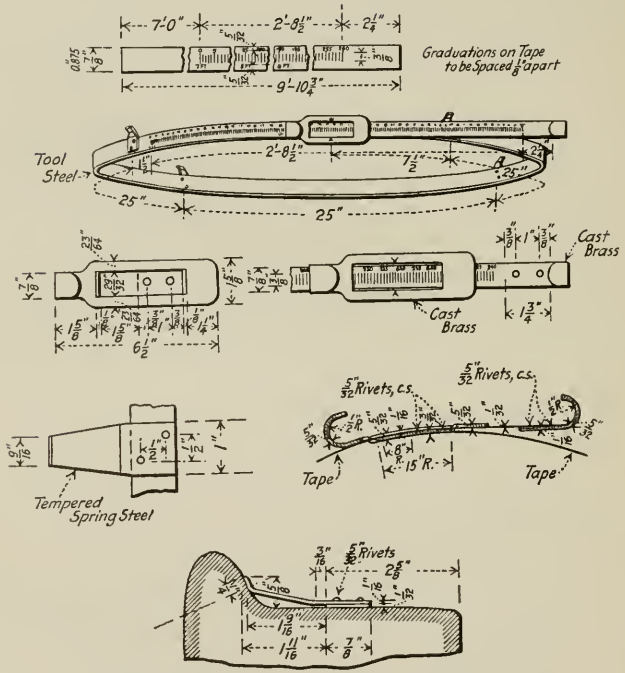
VII. INSPECTION AND REJECTION.

Inspection. 10. (*a*) The gages and tapes used shall be based on Master Car Builders' standards, as illustrated in Fig. 2.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser



(*a*) Plane Gage. (*b*) Rotundity Gage.



(*c*) Tape for Wheel Circumference Measure.

FIG. 2.—Master Car Builder's Standards.

is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of wheels in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*d*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

11. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 10 (*c*) shall be reported within five working days from the receipt of samples.

(*b*) Wheels which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

Rehearing.

12. Samples tested in accordance with Section 10 (*c*), which represent rejected wheels, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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STANDARD SPECIFICATIONS

FOR

STEEL CASTINGS.

Serial Designation: A 27 – 16.

The specifications for this material are issued under the fixed designation A 27; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1912, 1913, 1914, 1916.

Classes.

1. These specifications cover two classes of castings, namely:

Class A, ordinary castings for which no physical requirements are specified;

Class B, castings for which physical requirements are specified. These are of three grades: hard, medium, and soft.

Patterns.

2. (*a*) Patterns shall be made so that sufficient finish is allowed to provide for all variations in shrinkage.

(*b*) Patterns shall be painted three colors to represent metal, cores, and finished surfaces. It is recommended that core prints shall be painted black and finished surfaces red.

Basis of Purchase.

3. The purchaser shall indicate his intention to substitute the test to destruction specified in Section 11 for the tension and bend tests, and shall designate the patterns from which castings for this test shall be made.

I. MANUFACTURE.

Process.

4. The steel may be made by the open-hearth, crucible, or any other process approved by the purchaser.

Heat Treatment.

5. (*a*) Class A castings need not be annealed unless so specified.

(*b*) Class B castings shall be properly annealed, the treatment depending upon the design and chemical composition of the castings.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

6. The castings shall conform to the following requirements as to chemical composition:

	Class A.	Class B.
Carbon.....	not over 0.30 per cent	....
Phosphorus.....	" " 0.06 "	not over 0.05 per cent
Sulfur	....	" " 0.05 "

Ladle Analyses.

7. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 6.

Check Analyses.

8. (*a*) Analyses of Class A castings may be made by the purchaser. The phosphorus content thus determined shall not exceed that specified in Section 6 by more than 20 per cent. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface.

(*b*) Analyses of Class B castings may be made by the purchaser from a broken tension or bend test specimen. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 6 by more than 20 per cent. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface.

III. PHYSICAL PROPERTIES AND TESTS.

(For Class B Castings Only.)

Tension Tests.

9. (*a*) The castings shall conform to the following minimum requirements as to tensile properties:

	Hard.	Medium.	Soft.
Tensile strength, lb. per sq. in...	80 000	70 000	60 000
Yield Point, lb. per sq. in.....	0.45 tens. str.	0.45 tens. str.	0.45 tens. str
Elongation in 2 in., per cent....	15	18	22
Reduction of area, "	20	25	30

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

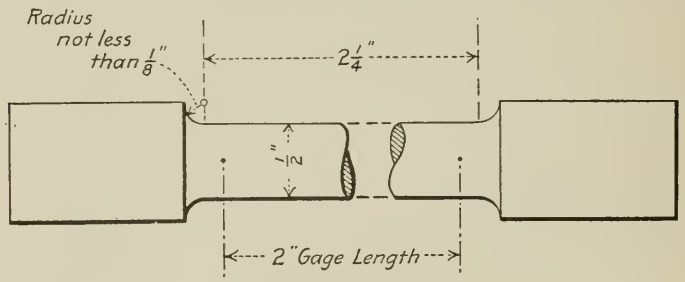
Bend Tests.

10. (*a*) The test specimen for soft castings shall bend cold through 120 deg., and for medium castings through 90 deg., around a 1-in. pin, without cracking on the outside of the bent portion.

(*b*) Hard castings shall not be subject to bend test requirements.

Alternative Tests to Destruction.

11. In the case of small or unimportant castings, a test to destruction on three castings from a lot may, upon agreement between the manufacturer and the purchaser, be substituted for the tension and bend tests. This test shall show the material to be ductile, free from injurious defects, and suitable for the



Note:- The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 1.

purpose intended. Unless otherwise agreed upon between the manufacturer and the purchaser, a lot shall consist of all castings from one melt, in the same annealing charge.

Test Specimens.

12. (*a*) Sufficient test bars, from which the test specimens required in Section 13 (*a*) may be selected, shall be attached to castings weighing 500 lb. or over, when the design of the castings will permit. If the castings weigh less than 500 lb., or are of such a design that test bars cannot be attached, two test bars shall be cast to represent each melt; or the quality of the castings shall be determined by tests to destruction as specified in Section 11. All test bars shall be annealed with the castings they represent.

(*b*) The manufacturer and purchaser shall agree whether test bars can be attached to castings, on the location of the bars on the castings, on the castings to which bars are to be attached, and on the method of casting unattached bars.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be machined to 1 by $\frac{1}{2}$ in. in section with corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

13. (*a*) One tension and one bend test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 9 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

14. If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-anneal such lot not more than twice and retests shall be made as specified in Sections 9 and 10.

IV. WORKMANSHIP AND FINISH.

Workmanship.

15. The castings shall substantially conform to the sizes and shapes of the patterns, and shall be made in a workmanlike manner.

Finish.

16. (*a*) The castings shall be free from injurious defects.

(*b*) Minor defects which do not impair the strength of the castings may, with the approval of the purchaser or his representative, be welded by an approved process. The defects shall first be cleaned out to solid metal; and after welding, the castings shall be annealed, if specified by the purchaser or his representative.

(*c*) Castings shall not be offered for inspection if covered with paint, rust, or any other substance to such an extent as to hide defects.

V. INSPECTION AND REJECTION.

Inspection.

17. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

18. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 8 shall be reported within five working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing.

19. Samples tested in accordance with Section 8, which represent rejected castings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

VI. SPECIAL REQUIREMENTS FOR CASTINGS FOR SHIPS.

Castings for Ships.

20. In addition to the preceding requirements, castings for ships, when so specified, shall conform to the following requirements:

Heat Treatment.

21. All castings shall be annealed.

Number of Tests.

22. (*a*) One tension and one bend test shall be made from each of the following castings: stern frames, stern posts, twin screw spectacle frames, propellor shaft brackets, rudders, steering quadrants, tillers, stems, anchors, and other castings when specified.

(*b*) When a casting is made from more than one melt, four tension and four bend tests shall be made from each casting.

23. (*a*) A percussion test shall be made on each of the following castings: stern frames, stern posts, twin screw spectacle frames, propellor shaft brackets, rudders, steering quadrants, tillers, stems, anchors, and other castings when specified. Percussion Tests.

(*b*) For this test, the casting shall be suspended by chains and hammered all over with a hammer of a weight approved by the purchaser or his representative. If cracks, flaws, defects, or weakness appear after such treatment, the casting will be rejected.

VII. SPECIAL REQUIREMENTS FOR CASTINGS FOR RAILWAY ROLLING STOCK.

24. Castings for railway rolling stock, when so specified, shall conform to the requirements for Class B castings, Sections 1 to 19, inclusive, except that check analyses made in accordance with Section 8 (*b*) shall conform to the requirements as to phosphorus and sulfur specified in Section 6. Castings for Railway Rolling Stock.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR LAP-WELDED AND SEAMLESS STEEL BOILER TUBES, BOILER FLUES, SUPERHEATER PIPES, SAFE ENDS, AND ARCH TUBES FOR LOCOMOTIVES.

Serial Designation: A 28 – 16.

The specifications for this material are issued under the fixed designation A 28; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1916.

I. MANUFACTURE.

Process.

1. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

2. The steel shall conform to the following requirements as to chemical composition:

Carbon	0.08 – 0.18 per cent
Manganese	0.30 – 0.50 "
Phosphorus	not over 0.04 "
Sulfur	" " 0.045 "

Check Analyses.

3. (*a*) Analyses of two tubes in each lot of 250 or less may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 2. Drillings for analyses shall be taken from several points around each tube.

(*b*) If the analysis of only one tube does not conform to the requirements specified, analyses of two additional tubes

from the same lot shall be made, each of which shall conform to the requirements specified.

III. PHYSICAL PROPERTIES AND TESTS.

Flange Tests.

4. (*a*) For all tubes except superheater pipes, a test specimen not less than 4 in. in length shall have a flange turned over at right angles to the body of the tube, without showing cracks or flaws. This flange, as measured from the outside of the tube, shall be $\frac{3}{8}$ in. wide for tubes $2\frac{1}{2}$ in. or under in outside diameter, and $\frac{1}{2}$ in. wide for tubes over $2\frac{1}{2}$ in. in outside diameter.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

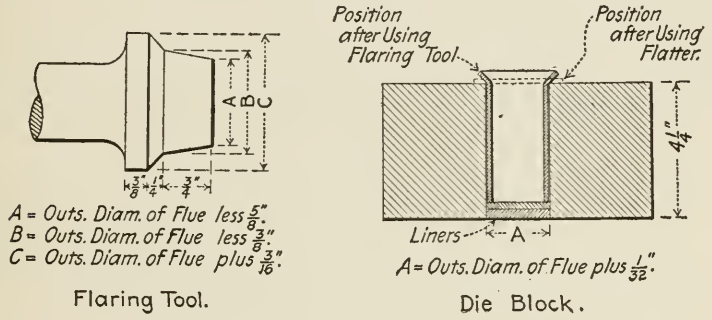


FIG. 1.

Flattening Tests.

5. (*a*) For all tubes except superheater pipes, a test specimen 4 in. in length shall stand flattening or hammering until the inside of the walls are in contact, without cracking at the edges or elsewhere. For lap-welded tubes, care shall be taken that the weld is not located at the point of maximum bending.

(*b*) For superheater pipes, a test specimen 4 in. in length shall stand flattening by pressure or hammering until the distance between the inside of the walls is equal to twice the thickness of the material, without cracking at the edges or elsewhere.

Crush Tests.

6. (*a*) For all tubes except superheater pipes, a test specimen $2\frac{1}{2}$ in. in length shall stand crushing longitudinally until the outside folds are in contact, without showing cracks or flaws.

(*b*) For superheater pipes, a test specimen $2\frac{1}{2}$ in. in length shall stand crushing longitudinally down to $1\frac{1}{4}$ in., without showing cracks or flaws.

Hydrostatic Tests.

7. Tubes under 5 in. in diameter shall stand an internal hydrostatic pressure of 1000 lb. per sq. in.; and tubes 5 in. or over in diameter shall stand an internal hydrostatic pressure of 800 lb. per sq. in.

Test Specimens.

8. (*a*) Test specimens shall consist of sections cut from tubes selected by the inspector representing the purchaser from the lot offered for shipment. They shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested cold.

Number of Tests.

9. One flange, one flattening, and one crush test shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test.

Retests.

10. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified in Sections 4, 5, or 6, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

IV. STANDARD WEIGHTS.

Standard Weights.

11. The standard weights for tubes of various outside diameters and thicknesses, are as indicated in Table I.

Permissible Variations.

12. The weight of the tubes shall not vary more than 5 per cent from that specified in Table I.

V. WORKMANSHIP AND FINISH.

Workmanship.

13. The finished tubes shall be circular within 0.02 in., and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. The thickness at any point shall not vary more than 10 per cent from that specified. In the case of boiler tubes which are expanded and swaged, the thickness of the expanded end may be $1\frac{1}{2}$ gages lighter, and of the swaged end 2 gages heavier than the thickness specified. The length shall not be less, but may be 0.125 in. more than that ordered.

Finish.

14. The finished tubes shall be free from injurious defects and shall have a workmanlike finish. They shall be free from kinks, bends, and buckles.

TABLE I.—STANDARD WEIGHTS.

LAP-WELDED AND SEAMLESS STEEL BOILER TUBES.

INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES.

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.													
In.	Nearest B. w. g. or Fraction.	1 3/4	1 7/8	2	2 1/4	2 1/2	3	3 1/2	4	4 1/2	5	5 1/4	5 3/8	5 1/2	6
0.095	13	1.679	1.806	1.932	2.186	2.440	.....	.....	.....	.....	.....	.....	.....	.....	.....
0.110	12	1.926	2.073	2.220	2.514	2.807	3.395	.....	.....	.....	.....	.....	.....	.....	.....
0.125	11	2.169	2.336	2.503	2.836	3.170	3.838	4.505	.....	.....	.....	.....	.....	.....	.....
0.135	10	2.328	2.508	2.688	3.049	3.409	4.130	4.851	5.572	.....	.....	.....	.....	.....	.....
0.150	9	2.560	.....	2.960	3.360	3.760	4.565	5.366	6.167	6.968	7.769	8.170	8.370	8.570	9.370
0.156	5/32	.....	.....	.....	.....	.....	4.745	5.579	6.414	7.248	8.083	8.500	8.708	8.917	.....
0.165	8	.....	.....	.....	.....	4.110	4.995	5.877	6.758	7.639	8.520	8.960	9.181	9.401	10.282
0.180	7	.....	.....	.....	.....	4.460	5.421	6.382	7.343	8.304	9.266	9.746	9.987	10.227	11.188
0.187	3/16	.....	.....	.....	.....	.....	5.632	6.633	7.634	8.635	9.637	10.137	10.388	10.638	11.639

SMALL SUPERHEATER PIPES.

SEAMLESS ONLY

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.											
In.	Nearest B. w. g. or Fraction.	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/4	1 3/8	1 7/16	1 1/2	1 5/8
0.095	13	0.5375	0.6012	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
0.109	12	.....	.....	0.7462	0.8190	.....	.....	.....	.....	.....	.....	.....	.....
0.120	11	.....	.....	.....	.....	0.9676	1.0480	1.1280	.....	.....	.....	.....	.....
0.135	10	.....	.....	.....	.....	.....	.....	.....	1.6100	1.7900	1.8800	1.9700	2.1500
0.150	9	.....	.....	.....	.....	.....	.....	.....	1.7600	1.9600	2.0600	2.1600	2.3600
0.156	5/32	.....	.....	.....	.....	.....	.....	.....	1.9100	2.1300	2.2400	2.3500	2.5700

VI. MARKING.

Marking. 15. The name or brand of the manufacturer, and "Tested at 1000 lb." for tubes under 5 in. in diameter, and "Tested at 800 lb." for tubes 5 in. or over in diameter, shall be legibly stenciled in white on each tube.

VII. INSPECTION AND REJECTION.

Inspection 16. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tubes ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 17. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 3 shall be reported within five working days from the receipt of samples.

(*b*) Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Superheater pipes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects. Tubes or superheater pipes which fail in either of the above operations will be rejected, and the manufacturer shall be notified.

Rehearing. 18. Samples tested in accordance with Section 3, which represent rejected tubes, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

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STANDARD SPECIFICATIONS

FOR

LAP-WELDED AND SEAMLESS STEEL AND WROUGHT-IRON BOILER TUBES FOR STATIONARY SERVICE.

Serial Designation: A 52 – 15.

The specifications for this material are issued under the fixed designation A 52; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1915.

I. MANUFACTURE.

Process.

1. (*a*) Lap-welded tubes shall be made of open-hearth steel or knobbled hammered charcoal iron.

(*b*) Seamless tubes shall be made of open-hearth steel.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

2. (*a*) The steel shall conform to the following requirements as to chemical composition:

Carbon	0.08 – 0.18 per cent
Manganese	0.30 – 0.50 "
Phosphorus	not over 0.04 "
Sulfur	" " 0.045 "

(*b*) Chemical analysis will not be required for charcoal-iron tubes.

Check Analyses.

3. (*a*) Analyses of two tubes in each lot of 250 steel tubes or less may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 2. Drillings for analyses shall be taken from several points around each tube.

(*b*) If the analysis of only one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

III. PHYSICAL PROPERTIES AND TESTS.

Flange Tests.

4. (*a*) A test specimen not less than 4 in. in length shall have a flange turned over at right angles to the body of the

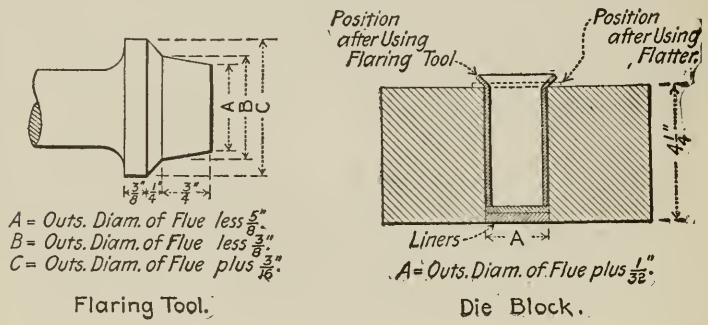

FIG. 1.

tube, without showing cracks or flaws. This flange, as measured from the outside of the tube, shall be $\frac{3}{8}$ in. wide for steel and $\frac{5}{16}$ in. wide for iron tubes.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Flattening Tests.

5. A test specimen 3 in. in length shall stand flattening or hammering until the inside of the walls are brought parallel and separated by a distance equal to three times the wall thickness, without showing cracks or flaws. In the case of lap-welded tubes, the test shall be made with the weld at the point of maximum bend.

Hydrostatic Tests.

6. Tubes under 5 in. in diameter shall stand an internal hydrostatic pressure of 1,000 lb. per sq. in.; and tubes 5 in. or over in diameter shall stand an internal hydrostatic pressure

of 800 lb. per sq. in. Lap-welded tubes shall be struck near both ends, while under pressure, with a 2-lb. hand hammer or the equivalent.

Etch Tests for Charcoal-Iron Tubes.[1]

7. A cross-section of charcoal-iron tube may be turned or ground to a perfectly true surface, polished free from dirt or cracks, and etched until the soft parts are sufficiently dissolved for the iron tube to show a decided ridged surface, with the weld very distinct, while a steel tube would show a homogeneous surface.

Test Specimens.

8. (*a*) All test specimens shall be taken from tubes before being cut to finished lengths and shall be smooth on the ends and free from burrs.

(*b*) All specimens shall be tested cold.

Number of Tests.

9. One flange and one flattening test shall be made from each of two tubes in each lot of 250 or less. Each tube shall be subjected to the hydrostatic test.

Retests.

10. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified in Sections 4 or 5, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

IV. WORKMANSHIP AND FINISH.

Workmanship.

11. (*a*) Finished tubes $3\frac{1}{2}$ in. or under in diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over $3\frac{1}{2}$ in. in diameter, these variations shall not exceed 0.5 per cent of the outside diameter. The measurements to determine whether the tubes meet these requirements shall be made near the ends of the tubes.

(*b*) All tubes shall be gaged with a B.w.g. gage and shall not be less than the thickness specified, except that tubes will be accepted on which the gage will go on tightly at the thinnest point.

(*c*) The length shall not be less, but may be 0.125 in. more than that ordered.

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[1] A solution of two parts water, one part concentrated hydrochloric acid, and one part concentrated sulfuric acid is recommended for the etch test.

Finish. 12. The finished tubes shall be free from injurious defects and shall have a workmanlike finish. They shall be practically free from kinks, bends and buckles.

V. MARKING.

Marking. 13. The name or brand of the manufacturer, the material from which it is made, whether steel or charcoal iron, and "Tested at 1000 lb." for tubes under 5 in. in diameter, and "Tested at 800 lb." for tubes 5 in. or over in diameter, shall be legibly stenciled on each tube.

VI. INSPECTION AND REJECTION.

Inspection. 14. Inspection and all tests except check analyses shall be made at the place of manufacture. The manufacturer shall furnish the purchaser of each lot of tubes a statement of the kind of material of which the tubes are made, and that the tubes have been tested and have met all the requirements of the specifications.

Rejection. 15. Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Tubes which fail in this manner will be rejected and the manufacturer shall be notified.

AMERICAN SOCIETY FOR TESTING MATERIALS

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR WELDED STEEL AND WROUGHT-IRON PIPE.

Serial Designation: A 53 - 15.

The specifications for this material are issued under the fixed designation A 53; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1915.

Basis of Purchase.

1. (*a*) All pipe to be used on locomotives and cars shall be of coiling or bending quality.

(*b*) Unless otherwise specified on the purchase order, inspection and all tests except the hydrostatic pressure test shall be made by the purchaser at destination, and at his expense.

I. MANUFACTURE.

Process.

2. (*a*) *Steel Pipe.*—Steel used in the manufacture of pipe shall be of a soft weldable quality made by the Bessemer or other approved process.

(*b*) *Wrought-Iron Pipe.*—The iron shall be made from muck bars, made from puddled pig iron, free from any admixture of iron scrap or steel.

(*c*) All pipe 3 in. or under in nominal diameter may be butt-welded, unless otherwise specified. All pipe over 3 in. in nominal diameter shall be lap-welded.

Definition of Terms.

3. *Iron Scrap.*—This term applies only to foreign or bought scrap and does not include local mill products, free from foreign or bought scrap.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

4. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

	Wrought Iron.	Steel.
Tensile strength, lb. per sq. in.....	45 000	50 000
Yield point, " "	24 000	30 000
Elongation in 8 in., per cent.....	12	18

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. For wrought-iron pipe, the speed of the cross-head of the machine shall not exceed $1\frac{1}{2}$ in. per minute.

Hydrostatic Tests.

5. All pipe shall be tested at the mill to the hydrostatic pressures specified in Table I.

Flattening Test for Steel Pipe.

6. A section of steel pipe 6 in. in length shall be flattened until the maximum distance between the walls is equal to three times the thickness of the material, without developing cracks, except at the weld.

Fracture Test for Wrought-Iron Pipe.

7. A section of wrought-iron pipe 6 in. in length shall be broken by repeated light blows of a hammer or by pressure; the fracture developed shall have a fibrous appearance.

Bend Test.

8. (*a*) For steel pipe, a sufficient length of pipe shall bend cold through 180 deg. around a mandrel the diameter of which is 18 times the nominal diameter of the pipe, without developing cracks in any portion, and without opening at the weld.

(*b*) For wrought-iron pipe, the test specified in Paragraph (*a*) shall be omitted, except for coiling or bending pipe.

Test Specimens.

9. (*a*) Test specimens shall consist of sections cut from a pipe. They shall be smooth on the ends and free from burrs.

(*b*) Tension test specimens shall be longitudinal.

(*c*) All specimens shall be tested cold.

Number of Tests.

10. One of each of the tests specified in Sections 4, 6 or 7, and 8, may be made on a length in each lot of 500 or less, of each size. Each length shall be subjected to the hydrostatic test.

Retests.

11. If the results of the physical tests of any lot do not conform to the requirements specified in Sections 4, 6 or 7,

and 8, retests of two additional pipes shall be made, each of which shall conform to the requirements specified.

III. STANDARD WEIGHTS.

Standard Weights.

12. (*a*) The standard weights for pipe of various inside diameters are given in Table II.

(*b*) Nipples shall be cut from pipe of the same weight and quality as described in these specifications.

TABLE I.—HYDROSTATIC PRESSURES FOR WELDED PIPE.
(PRESSURE EXPRESSED IN POUNDS PER SQUARE INCH.)

Inside Diameter, in.	Standard-Grade Pipe.		Extra-Strong Pipe.	
	Butt-Weld.	Lap-Weld.	Butt-Weld.	Lap-Weld.
$\frac{1}{8}$	700	....	700	....
$\frac{1}{4}$	700	....	700	....
$\frac{3}{8}$	700	....	700	....
$\frac{1}{2}$	700	....	700	....
$\frac{3}{4}$	700	....	700	....
1	700	....	700	....
$1\frac{1}{4}$	700	1000	1500	2500
$1\frac{1}{2}$	700	1000	1500	2500
2	700	1000	1500	2500
$2\frac{1}{2}$	800	1000	1500	2000
3	800	1000	1500	2000
$3\frac{1}{2}$	...	1000	....	2000
4	...	1000	....	2000
$4\frac{1}{2}$	...	1000	....	1800
5	...	1000	....	1800
6	...	1000	....	1800

Permissible Variations.

13. The weight of the pipe shall not vary more than 5 per cent from that specified in Section 12 (*a*).

IV. WORKMANSHIP AND FINISH.

Workmanship.

14. (*a*) For pipe $1\frac{1}{2}$ in. or under, the outside diameter, at any point, shall not vary more than $\frac{1}{64}$ in. over nor more than $\frac{1}{32}$ in. under the standard. For pipe 2 to 6 in., inclusive, the outside diameter shall not vary more than 1 per cent over nor more than $\frac{3}{64}$ in. under the standard.

(*b*) All standard-weight pipe shall be provided with the prevailing standard thread, which will make a tight joint when tested to the internal hydrostatic pressure at the mill. The threads shall not vary more than one and one-half turns either way, when tested with a Pratt & Whitney standard gage. All burrs at the end of the pipe shall be removed.

(*c*) Unless otherwise ordered, pipe shall be furnished in random lengths of 16 to 22 ft., but not more than 5 per cent

TABLE II.—STANDARD WEIGHTS.

(ALL DIMENSIONS ARE NOMINAL.)

Dimensions.			Standard-Grade Pipe.	Extra-Strong Pipe.
Inside Diameter, in.	Number of Threads per Inch.	Outside Diameter, in.	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Weight of Pipe per Linear Foot, Plain Ends, lb.
$\frac{1}{8}$	27	0.405	0.25	0.31
$\frac{1}{4}$	18	0.540	0.43	0.54
$\frac{3}{8}$	18	0.675	0.57	0.74
$\frac{1}{2}$	14	0.840	0.85	1.09
$\frac{3}{4}$	14	1.050	1.13	1 47
1	$11\frac{1}{2}$	1.315	1.68	2.17
$1\frac{1}{4}$	$11\frac{1}{2}$	1.660	2.28	3.00
$1\frac{1}{2}$	$11\frac{1}{2}$	1.900	2.73	3.63
2	$11\frac{1}{2}$	2.375	3.68	5.02
$2\frac{1}{2}$	8	2.875	5.82	7.66
3	8	3.500	7.62	10.25
$3\frac{1}{2}$	8	4.000	9 20	12.51
4	8	4.500	10.89	14.98
$4\frac{1}{2}$	8	5.000	12.64	17.61
5	8	5.563	14.81	20.78
6	8	6.625	19.19	28.57

of the total number of lengths furnished may be "jointers," which are two pieces coupled together. When ordered with plain ends, 5 per cent may be furnished in lengths of 12 ft. or over.

(*d*) Each standard-weight pipe shall be provided with a coupling, having clean-cut threads of such a pitch diameter as to make a tight joint. For steel pipe, couplings may be of

wrought iron or steel. For wrought-iron pipe, couplings shall be of wrought iron.

(*e*) Unless otherwise specified, extra-strong pipe shall be furnished in random lengths, with plain ends.

15. The finished pipe shall be reasonably straight and free from injurious defects. **Finish.**

V. INSPECTION AND REJECTION.

16. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the pipe are being furnished in accordance with these specifications. **Inspection.**

(*b*) When tests and inspection are made at the place of manufacture, they shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. Pipe which develop injurious defects in shop working or application will be rejected, and the manufacturer shall be notified. **Rejection.**

18. Samples tested in accordance with Section 1 (*b*), which represent rejected pipe, shall be preserved for two weeks from the date of test report. In case of dissatisfaction with results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR AUTOMOBILE CARBON AND ALLOY STEELS.

Serial Designation: A 29 – 16.

The specifications for this material are issued under the fixed designation A 29; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1915, 1916.

Basis of Purchase.

1. Automobile steels shall be purchased on the basis of the requirements as to chemical composition specified in Sections 5, 6 and 7. Requirements as to physical properties have been omitted for all steels except castings, because the majority of automobile steels, except castings, are either worked or given special heat treatments by the purchaser. It is recommended that tension and bend tests shall be specified for the material as shipped, whenever it is practicable to do so. When physical requirements are specified, requirements as to carbon shall be omitted.

Steel Castings.

2. The Standard Specifications for Steel Castings, Class B (Serial Designation: A 27), adopted by the American Society for Testing Materials, shall govern the purchase of automobile steel castings.

I. MANUFACTURE.

Process.

3. The steels may be made by the Bessemer, open-hearth, crucible, electric, or any other process approved by the purchaser.

Discard.

4. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

5. The steels shall conform to the requirements as to chemical composition specified in Tables I to VI, appended to these specifications, and which are entitled as follows:

TABLE.	TITLE.
I.....	Automobile Carbon Steels.
II.....	Automobile Nickel Steels.
III.....	Automobile Nickel-Chromium Steels.
IV.....	Automobile Chromium Steels.
V.....	Automobile Chromium-Vanadium Steels.
VI.....	Automobile Silico-Manganese Steels.

Ladle Analyses.

6. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Tables I to VI. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot obtained during the pouring of the melt, and in as sound metal as possible. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Tables I to VI.

Check Analyses.

7. (*a*) Analyses may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Tables I to VI.

(*b*) Drillings for analyses of bars, billets, or other regular shapes shall be taken parallel to the axis, at any point midway between the center and surface.

(*c*) Drillings for analyses may be taken from broken tension or bend test specimens, if physical requirements are specified.

(*d*) Drillings or cuttings for analyses of irregularly shaped pieces for which no physical requirements are specified, shall be taken from both the thickest and the thinnest sections. Surface drillings shall be discarded.

(*e*) Wire, tubing, sheets, and rods less than $1\frac{1}{4}$ in. in thickness, shall be sampled through or across the entire section.

III. PHYSICAL PROPERTIES AND TESTS.

Physical Properties.

8. If physical requirements are specified, the following Sections 9 to 13 shall form a part of the modified specifications.

Yield Point.

9. The yield point shall be determined by the drop of the beam of the testing machine.

Elastic Limit.

10. The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

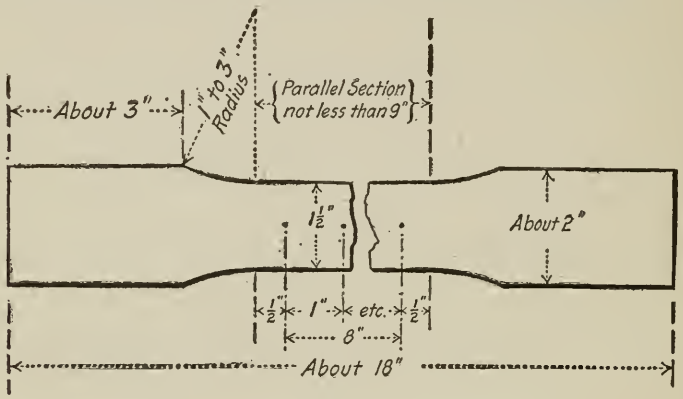


FIG. 1.

Bend Tests.

11. The bend test shall be made cold.

Test Specimens.

12. (*a*) Tension and bend test specimens shall be taken from the rolled or forged material; except that in the case of irregularly shaped forgings, they may be taken from a full-size prolongation. Specimens shall not be annealed or otherwise treated, except as specified in Paragraph (*b*).

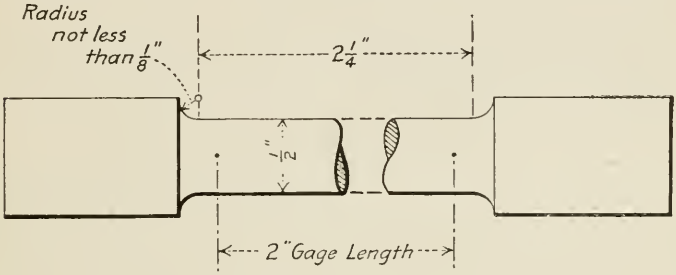
(*b*) Tension and bend test specimens for material which is to be annealed or otherwise treated before use shall be cut, for rolled material, from properly annealed or similarly treated short lengths of the full section of the piece, and for forged material from the treated forgings.

(*c*) Tension and bend test specimens for plates and shapes shall be of the full thickness of material as rolled; and may be

machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*d*) Tension and bend test specimens for rolled bars and forgings of uniform cross-section $1\frac{1}{2}$ in. or under in thickness or diameter, may be of the full-size section of material as rolled or forged, or may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in. Tension test specimens shall be of 8-in. gage length.

(*e*) The axis of tension and bend test specimens for rolled bars and forgings of uniform cross-section over $1\frac{1}{2}$ in. in thickness or diameter, and for forgings of irregular sections, when practicable, shall be located at any point midway between the center



Note:– The Gage Length, Parallel Portions and Fillets shall be as Shown, but the Ends may be of any Form which will Fit the Holders of the Testing Machine.

FIG. 2.

and surface when solid, and at any point midway between the inner and outer surfaces of the wall when bored, and shall be parallel to the axis of the piece in the direction in which the metal is most drawn out. Tension test specimens shall conform to the dimensions shown in Fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be $\frac{1}{2}$ in. square in section with corners rounded to a radius not over $\frac{1}{16}$ in., and need not exceed 6 in. in length.

Number of Tests.

13. (*a*) Unless otherwise specified by the purchaser, one tension and one bend test shall be made from each melt; except that if material rolled from one melt differs $\frac{3}{8}$ in. or more in

thickness, one tension and one bend test shall be made from both the thickest and the thinnest material.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. FINISH.

Finish. 14. The material shall be free from injurious defects and shall have a workmanlike finish.

V. INSPECTION AND REJECTION.

Inspection. 15. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 15 (*b*) shall be reported within ten working days from the receipt of samples.

(*b*) Material which shows injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

17. Samples tested in accordance with Section 15(*b*), which represent rejected material, shall be preserved for one month from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

TABLE I.—AUTOMOBILE CARBON STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over
0.10	0.05–0.15	0.45	0.30–0.60	0.045	0.05
0.20	0.15–0.25	0.45	0.30–0.60	"	"
0.25	0.20–0.30	0.65	0.50–0.80	"	"
0.35	0.30–0.40	0.65	0.50–0.80	"	"
0.45	0.40–0.50	0.65	0.50–0.80	"	"
0.95	0.90–1.05	0.35	0.25–0.50	0.04	"
SCREW STOCK.					
0.14	0.08–0.20	0.55	0.30–0.80	0.12	0.06–0.12
STEEL CASTINGS, CLASS B.					
As required for the chemical and physical properties. See Standard Specifications for Steel Castings (Serial Designation: A 27).					

All values are expressed in per cent.

TABLE II.—AUTOMOBILE NICKEL STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.	NICKEL.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.
0.15	0.10–0.20	0.65	0.50–0.80	0.04	0.045	3.50	3.25–3.75
0.20	0.15–0.25	"	" "	"	"	"	" "
0.30	0.25–0.35	"	" "	"	"	"	" "
0.35	0.30–0.40	"	" "	"	"	"	" "
0.40	0.35–0.45	"	" "	"	"	"	" "

All values are expressed in per cent.

TABLE III.—AUTOMOBILE NICKEL-CHROMIUM STEELS.

WITH 1.25 PER CENT NICKEL.

CARBON.		MANGANESE.		PHOS.	SULF.	NICKEL.		CHROMIUM.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.	Desired.	Permissible Range.
0.20	0.15–0.25	0.65	0.50–0.80	0.04	0.045	1.25	1.00–1.50	0.60	0.45–0.75
0.25	0.20–0.30	"	" "	"	"	"	" "	"	" "
0.30	0.25–0.35	"	" "	"	"	"	" "	"	" "
0.35	0.30–0.40	"	" "	"	"	"	" "	"	" "
0.40	0.35–0.45	"	" "	"	"	"	" "	"	" "

WITH 1.75 PER CENT NICKEL.

0.20	0.15–0.25	0.45	0.30–0.60	0.04	0.04	1.75	1.50–2.00	1.10	0.90–1.25
0.30	0.25–0.35	"	" "	"	"	"	" "	"	" "
0.40	0.35–0.45	"	" "	"	"	"	" "	"	" "
0.50	0.45–0.55	"	" "	"	"	"	" "	"	" "

WITH 3.00 PER CENT NICKEL.

0.15	0.10–0.20	0.60	0.45–0.75	0.04	0.04	3.00	2.75–3.25	0.80	0.60–0.95
0.35	0.30–0.40	"	" "	"	"	"	" "	"	" "
0.50	0.45–0.55	"	" "	"	"	"	" "	"	" "

WITH 3.50 PER CENT NICKEL.

0.20	0.15–0.25	0.45	0.30–0.60	0.04	0.04	3.50	3.25–3.75	1.50	1.25–1.75
0.30	0.25–0.35	"	" "	"	"	"	" "	"	" "
0.40	0.35–0.45	"	" "	"	"	"	" "	"	" "

All values are expressed in per cent.

TABLE IV.—AUTOMOBILE CHROMIUM STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.	CHROMIUM.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.
0.20	0.15–0.25	.....[a]	.....[a]	0.04	0.045	0.75	0.65–0.85
0.40	0.35–0.45	.....[a]	.....[a]	"	"	"	" "
0.65	0.60–0.70	.....[a]	.....[a]	"	"	"	" "
0.95	0.90–1.05	0.35	0.20–0.45	0.03	0.03	1.00	0.90–1.10
1.20	1.10–1.30	"	" "	"	"	"	" "
0.95	0.90–1.05	"	" "	"	"	1.20	1.10–1.30
1.20	1.10–1.30	"	" "	"	"	"	" "

[a] In these three grades the specified percentages of manganese and silicon may be either of the following: manganese, 0.35 desired (permissible range, 0.25 – 0.50) and silicon, not over 0.20; or manganese, 0.70 desired (permissible range, 0.60 – 0.80) and silicon, 0.15 – 0.50.

All values are expressed in per cent.

TABLE V.—AUTOMOBILE CHROMIUM-VANADIUM STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.	CHROMIUM.		VANADIUM.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.	Desired.	Not Under.
0.20	0.15–0.25	0.65	0.50–0.80	0.04	0.04	0.95	0.80–1.10	0.18	0.15
0.25	0.20–0.30	"	" "	"	"	"	" "	"	"
0.30	0.25–0.35	"	" "	"	"	"	" "	"	"
0.35	0.30–0.40	"	" "	"	"	"	" "	"	"
0.40	0.35–0.45	"	" "	"	"	"	" "	"	"
0.45	0.40–0.50	"	" "	"	"	"	" "	"	"
0.50	0.45–0.55	"	" "	"	"	"	" "	"	"
0.95	0.90–1.05	0.35	0.20–0.45	0.03	0.03	"	" "	"	"

All values are expressed in per cent.

TABLE VI.—AUTOMOBILE SILICO-MANGANESE STEELS.

CARBON.		MANGANESE.		PHOS.	SULF.	SILICON.	
Desired.	Permissible Range.	Desired.	Permissible Range.	Not Over	Not Over	Desired.	Permissible Range.
0.50	0.45–0.55	0.70	0.60–0.80	0.045[a]	0.045	1.95	1.80–2.10
0.60	0.55–0.65	0.60	0.50–0.70	0.045[a]	0.045	1.65	1.50–1.80

[a] Steels made by the acid process may contain 0.05 maximum phosphorus.

All values are expressed in per cent.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR BOILER AND FIREBOX STEEL FOR LOCOMOTIVES.

Serial Designation: A 30 – 16.

The specifications for this material are issued under the fixed designation A 30; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914, 1916.

Grades. 1. These specifications cover two grades of steel for boilers for locomotives, namely: flange and firebox.

I. MANUFACTURE.

Process. 2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

		Flange.	Firebox.
Carbon		.....	0.12 – 0.25 per cent
Manganese		0.30 – 0.60	0.30 – 0.50 "
Phosphorus	Acid	not over 0.05	not over 0.04 "
	Basic	" " 0.04	" " 0.035 "
Sulfur		" " 0.05	" " 0.04 "
Copper		.....	" " 0.05 "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements

specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses.

5. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The material shall conform to the following requirements as to tensile properties:

	Flange.	Firebox.
Tensile strength, lb. per sq. in.....	55 000 – 65 000	52 000 – 62 000
Yield point, min., " "	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent.. (See Section 7)	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction of 0.5 from the percentages of elongation specified in Section 6(*a*) shall be made for each increase of $\frac{1}{8}$ in. in thickness above $\frac{3}{4}$ in.

(*b*) For material $\frac{1}{4}$ in. or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

Bend Tests.

8. The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

Homogeneity Tests.

9. For firebox steel, a sample taken from a broken tension test specimen shall not show any single seam or cavity more than $\frac{1}{4}$ in. long, in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about $\frac{1}{16}$ in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about $\frac{1}{4}$ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any

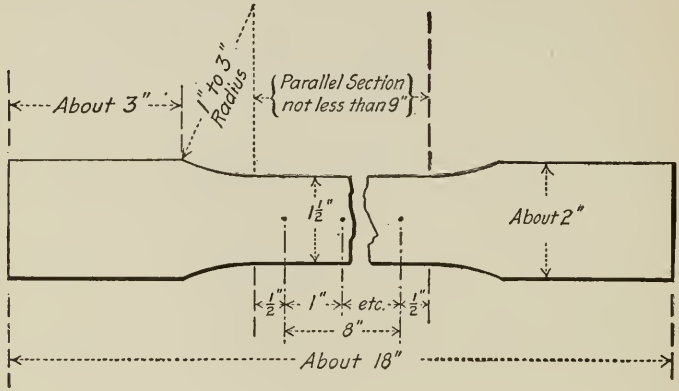


FIG. 1.

cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the lengths of the seams and cavities determined, a pocket lens being used if necessary.

Test Specimens. 10. (*a*) Tension test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimens shall be taken in the direction of the longitudinal axis of the ingot, and the transverse test specimens at right angles to that axis.

(*b*) Tension and bend test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

11. (*a*) One tension and one bend test shall be made from each plate as rolled. **Number of Tests.**

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

12. *When Ordered to Thickness.*—The thickness of each plate shall not vary more than 0.01 in. under that ordered. **Permissible Variations.**

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108in., excl.	108 to 120in., excl.	120 to 132in., excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

[1] The term "lot" applied to Table I means all of the plates of each group width and group thickness.

V. FINISH.

Finish.

13. The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking.

14. (*a*) The name or brand of the manufacturer, melt or slab number, grade, and lowest tensile strength for its grade specified in Section 6 (*a*), shall be legibly stamped on each plate. The melt or slab number shall be legibly stamped on each test specimen.

(*b*) When specified on the order, plates shall be match-marked as defined in Paragraph (*c*) so that the test specimens representing them may be identified. When more than one plate is sheared from a single slab or ingot, each shall be match-marked so that they may all be identified with the test specimen representing them.

(*c*) Each match mark shall consist of two over-lapping circles each not less than $1\frac{1}{2}$ in. in diameter, placed upon the shear lines, and made by separate impressions of a single-circle steel die.

(*d*) Match-marked coupons shall match with the sheets represented and only those which match properly shall be accepted.

VII. INSPECTION AND REJECTION.

Inspection.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

17. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. Rehearing.

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STANDARD SPECIFICATIONS

FOR

BOILER RIVET STEEL.

Serial Designation: A 31 – 14.

The specifications for this material are issued under the fixed designation A 31; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914.

A. Requirements for Rolled Bars.

I. MANUFACTURE.

Process.

1. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

2. The steel shall conform to the following requirements as to chemical composition:

Manganese	0.30 – 0.50 per cent
Phosphorus	not over 0.04 "
Sulfur	" " 0.045 "

Ladle Analyses.

3. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 2.

4. Analyses may be made by the purchaser from finished bars representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 2. Check Analyses.

III. PHYSICAL PROPERTIES AND TESTS.

5. (*a*) The bars shall conform to the following requirements as to tensile properties: Tension Tests.

Tensile strength, lb. per sq. in.	45 000 – 55 000
Yield point, min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent.	$\frac{1\,500\,000}{\text{Tens. str.}}$, but need not exceed 30 per cent.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

6. (*a*) *Cold-bend Tests.*—The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion. Bend Tests.

(*b*) *Quench-bend Tests.*—The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200° F.), and quenched at once in water the temperature of which is between 80° and 90° F., shall bend through 180 deg. flat on itself without cracking on the outside of the bent portion.

7. Tension and bend test specimens shall be of the full-size section of bars as rolled. Test Specimens.

8. (*a*) Two tension, two cold-bend, and two quench-bend tests shall be made from each melt, each of which shall conform to the requirements specified. Number of Tests.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN DIAMETER.

9. The diameter of each bar shall not vary more than 0.01 in. from that specified. Permissible Variations.

V. WORKMANSHIP AND FINISH.

Workmanship. 10. The finished bars shall be circular within 0.01 in.

Finish. 11. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING.

Marking. 12. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

VII. INSPECTION AND REJECTION

Inspection. 13. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 14. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 15. Samples tested in accordance with Section 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. Requirements for Rivets.

VIII. PHYSICAL PROPERTIES AND TESTS.

16. The rivets, when tested, shall conform to the require- Tension Tests.
ments as to tensile properties specified in Section 5, except that the elongation shall be measured on a gage length not less than four times the diameter of the rivet.

17. The rivet shank shall bend cold through 180 deg. flat Bend Tests.
on itself, as shown in Fig. 1, without cracking on the outside of the bent portion.

18. The rivet head shall flatten, while hot, to a diameter Flattening Tests.
$2\frac{1}{2}$ times the diameter of the shank, as shown in Fig. 2, without cracking at the edges.

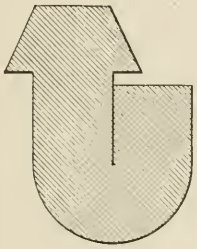


FIG. 1.

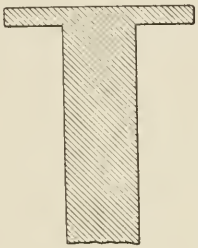


FIG. 2.

19. (*a*) When specified, one tension test shall be made from Number of Tests.
each size in each lot of rivets offered for inspection.

(*b*) Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

IX. WORKMANSHIP AND FINISH.

20. The rivets shall be true to form, concentric, and shall Workmanship.
be made in a workmanlike manner.

21. The finished rivets shall be free from injurious defects. Finish.

X. INSPECTION AND REJECTION.

22. The inspector representing the purchaser shall have free Inspection.
entry, at all times while work on the contract of the purchaser is

being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 23. Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

RECOMMENDED PRACTICE FOR ANNEALING OF MISCELLANEOUS ROLLED AND FORGED CARBON-STEEL OBJECTS.

Serial Designation: A 35–11.

This recommended practice is issued under the fixed designation A 35; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1911.

1. *Purpose and General Procedure.*—The usual purpose in annealing miscellaneous forged or rolled carbon-steel objects is to remove existing coarseness of grain. This removal is brought about by heating the object to an annealing temperature, which varies with the carbon content of the metal. But the rate at which the object cools from this annealing temperature influences its properties very profoundly. Hence this rate of cooling should be suited to the duties which the object has to perform in service, and hence to the properties which we seek to give it.

Therefore these specifications first consider the annealing temperature to which the piece must be heated in order to remove existing coarse grain, and then the rate of cooling from that temperature.

Under certain special conditions an annealing is required in order to remove, not coarseness of grain, but the effects of rolling or otherwise working the metal at a temperature so low as to set up serious internal stress. Appropriate treatment for these conditions is given in Section 14.

As these specifications are intended to apply to a great variety of miscellaneous objects, they are purposely made suggestive rather than mandatory in many respects, because no single set of rules can be applied rigorously to such widely varying classes of objects and purposes.

ANNEALING FOR REMOVING EXISTING COARSE GRAIN.

2. *Method of Heating.*—In the case of large objects, the heating of the interior of which lags behind that of the outside, though the early part of the heating may if desired be rapid, the final approach to the annealing temperature aimed at should be slow, so that the interior may be brought fully up to it without carrying the exterior far beyond it, because in general any needlessly high temperature is injurious, and tends to re-coarsen the grain. The temperature should be held long enough at the annealing point to insure that the whole of the interior reaches that point, and that the refining of the grain may become complete. An exposure of one hour should be long enough for pieces 12 in. thick. Thicker pieces need a longer heating.

3. *Control of Temperature. Pyrometers.*—For all important work in careful hands the use of some trustworthy pyrometer is strongly recommended. But most pyrometers should be checked frequently against some standard. For those who are unwilling to take this trouble it is safer to rely on a trained eye than on an unchecked pyrometer. The operator should have clearly before him the fact that no pyrometer indicates the temperature of the interior of the object heated, and that the temperature which most pyrometers indicate is one between the temperature of the outside of the object heated and the temperature of the flame which is supplying the heat. Wherever practicable the part of the pyrometer which is supposed to reach the temperature of the object heated should be in immediate contact with that object, and should be protected from the flame or other source of heat by a suitable insulation, as for instance by covering it with sand. In important cases the gas or other source of heat should be shut off for at least ten minutes before taking the observation.

4. *Control Without the Use of a Pyrometer.*—In working without a pyrometer and relying on the eye, the light surrounding the furnace should be dull, and should be kept as nearly constant as practicable, in order that the eye may not be misled

by the changing contrasts between the surrounding light and that of the object heated. In particular, direct sunlight should be excluded, and any arc or other strong lights should be so placed that neither they themselves nor any concentrated part of their light is in the field of the operator's sight when he is estimating by eye the temperature of the objects to be annealed. Allowance should be made for the brighter surroundings by day than at night, and on sunny than on dark days.

5. *Magnetic Indications.*—The annealing temperature for steels containing between 0.50 and 0.90 per cent of carbon is that at which the metal suddenly ceases to be magnetic. This fact may sometimes be used for the purpose of fixing or verifying the annealing temperature.

6. *Annealing Temperature.*—In general, the higher the carbon content the lower should be the annealing temperature. Hence different temperatures are given for different ranges of carbon content. Further, in order to bring the interior of large objects up to an effective annealing temperature, their outside may often be raised advantageously somewhat above that temperature. Hence for each range of carbon content a range of temperature is given. The upper limit of this range applied (1) to larger objects, and (2) to the lower part of the range of carbon content given.

The following ranges of temperature should be used for the several ranges of carbon content indicated. They refer to the usual moderate manganese content. For steels with a manganese content greater than 0.75 per cent slightly lower temperatures suffice.

RANGE OF CARBON CONTENT.	RANGE OF ANNEALING TEMPERATURE.
Less than 0.12 per cent	875 to 925° C. (1607–1697° F.)
0.12 to 0.29 "	840 " 870 " (1544–1598 ")
0.30 " 0.49 "	815 " 840 " (1499–1544 ")
0.50 " 1.00 "	790 " 815 " (1454–1499 ")

7. *Care in Heating.*—Care should be taken that all parts of the object reach the same temperature. To that end it may be necessary to mask from the heat, by means of bricks, the thinner part of objects of varying thickness. When the heating is nearly finished, these bricks may be removed. In particular the flame should never be allowed to touch any part of the object under treatment.

8. *Cooling.*—After the object has been held at the annealing temperature long enough to make its temperature nearly uniform throughout, and to complete the refining of the grain, it should

be cooled in a way suited to its carbon content and to giving it the specific properties needed. The general principles are: first, the higher the carbon the slower should be the cooling; and second, the slower the cooling the softer and more ductile the metal will be, and the lower will be its tensile strength, elastic limit, and yield point. The greatest softness and ductility are obtained at a certain sacrifice of strength and elasticity, and the greatest strength and elasticity at a certain sacrifice of softness and ductility.

For most purposes neither of these extremes is desired, and it is not only sufficient as regards quality but economical to remove the object from the furnace as soon as it has been thoroughly annealed, and to allow it to cool in air, always completely protected not only from rain and snow but from sharp drafts of air. Objects containing more than 0.50 per cent of carbon should cool more slowly till the color dies out, say at 500° C. (932° F.), as for instance by leaving them in the furnace. They may then be removed and cooled in air. Further, thin objects containing between 0.25 and 0.50 per cent of carbon should be treated like those of 0.50 per cent of carbon, unless they can be so massed together that their collective bulk will retard their cooling, so that they will collectively cool even in air with moderate slowness, like single large objects.

SPECIAL ANNEALING METHODS.

9. The foregoing methods are economical because they release the furnaces early for further use. In case special qualities are desired the following methods may be used:

10. *To Give the Greatest Softness and Ductility* of which the metal is capable, even at a certain sacrifice of strength and elastic limit, for instance for ease of machining or to resist a small number of severe distortions, the metal should be cooled slowly, either within the furnace, or in the case of large objects, under a cover of lime, clay, or other slow conductor of heat. The slower the cooling and the lower the temperature to which slow cooling is carried, the softer and weaker will be the steel. But for most cases for which even unusual softness and ductility are required, it suffices to remove the object from the furnace when it has become dead black, and to cool it thenceforth in air.

11. *To Give Great Tensile Strength and High Elastic Limit* even at a certain sacrifice of ductility, the cooling should be

more rapid, the rapidity to be governed by the thickness and carbon content of the object. Thin objects and those with high carbon content cannot stand so rapid a cooling as thick and low-carbon ones, lest their ductility be too far sacrificed. For instance, thick objects with less than 0.50 per cent of carbon may be cooled completely in air, of course protected from rain or snow. Objects with 0.50 per cent of carbon or more, and thin objects with from 0.30 to 0.50 per cent of carbon, may be cooled in air if their cooling is somewhat retarded, as for instance by massing them together, as happens in the case of rails.

12. *To Give an Unusually High Combination of Ductility with Tensile Strength and Elastic Limit. Water or Oil Quenching and Annealing.*—This process needs great care and intelligence, and should in general be used only by those familiar with high-grade steels. After holding at the annealing temperature suited to the particular steel, as indicated in Section 6, the object is quenched in oil, which should be kept in circulation. It may be quenched in water if its carbon content is so low and its shape so simple that it is not in danger of cracking or receiving permanently harmful stress. In any event the danger of such cracking and stress is lessened by removing the object from the oil or water before it has cooled completely, say when its temperature has fallen to 160° C. (320° F.). It should if possible not cool below 100° C. (212° F.) and certainly not below 20° C. (68° F.). The annealing should begin within a very few hours after the quenching and if possible without ever allowing the piece to cool below 100° C. (212° F.) and certainly not below 20° C. (68° F.).

The steel thus hardened should next be annealed by heating to a temperature suited for giving the properties needed. In general the higher this annealing goes, the more ductile will the steel become, and the lower will be its strength and elastic limit.

For very high elastic limit and tensile strength, anneal at 500 to 650° C. (932 to 1202° F.). In this case the ductility will be low. Some steels, such as watch-springs and shafting, are annealed at 350° C. Little commercial annealing is done below 500° C.

For intermediate tensile strength, elastic limit, and ductility, best suited to the majority of cases, anneal at 600 to 650° C. (1112 to 1202° F.).

For the greatest ductility, with good strength and elastic limit, anneal at from 725 to 750° C. (1337 to 1382° F.).

The object should be held at this second annealing temperature long enough not only to allow its interior to reach it, but also to relieve the stress given in the water or oil quenching. For pieces of moderate thickness a 4-hour exposure should suffice.

13. *To Give a Moderate Increase of Strength and Elastic Limit above that Given by a Simple Slow Cooling, without the Full Sacrifice of Ductility which a Simple Air Cooling would Cause.*—After holding at the annealing temperature suited to the carbon content, as indicated in Section 6, hasten the cooling till the object is at a dull red, say 650° C. (1202° F.), and henceforth cool slowly. The hastening of the cooling may be brought about in the case of thin objects in relatively shallow furnaces by opening the furnace door till the temperature falls to dull redness; or by running the objects out into the air on a movable car-bottom, and returning them to the furnace when they have cooled to dull redness; or even, in the case of objects with not over 0.30 per cent carbon and not too thin, by a temporary immersion in oil or even water, followed by a return to the furnace. In cases in which such operations are to be performed frequently, special unfired chambers may be used for the final slow cooling, thus leaving the annealing furnaces proper available for their regular work. The results obtained in this way are not as good as those obtained with the method described in Section 11.

14. *Special Annealing to Remove the Effects of Rolling or Otherwise Working the Object in the Cold or at any Unduly Low Temperature.*—The object should be heated to about 775° C. (1427° F.) and cooled with a slowness which should increase with the thickness, that is, the least dimension of the piece. In the case of thin plates a mere heating to 725° C. (1337° F.), followed immediately by slow cooling, should suffice. In the case of thick forgings, in which much time may be needed to allow severe stress to relieve itself, the sojourn at 775° C. (1427° F.) may be prolonged for several hours, though always at the cost of superficial decarburizing.

Such annealing for steel containing less than 0.15 per cent carbon should be at 900° C. (1652° F.). Great brittleness may be caused by annealing very low carbon steel in the neighborhood of 700° C. (1292° F.), after cold working.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR STAYBOLT IRON.

Serial Designation: A 39 – 14.

The specifications for this material are issued under the fixed designation A 39; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1910; REVISED, 1912, 1914.

I. MANUFACTURE.

Process.

1. The iron shall be rolled from a bloom or boxpile, made wholly from puddled iron or knobbled charcoal iron. The puddle mixture and the component parts of the bloom or boxpile shall be free from any admixture of iron scrap or steel.

Definition of Terms.

2. (*a*) *Bloom.*—A bloom is a solid mass of iron that has been hammered into a convenient size for rolling.

(*b*) *Boxpile.*—A boxpile is a pile, the sides, top and bottom of which are formed by four flat bars and the interior of which consists of a number of small bars the full length of the pile.

(*c*) *Iron Scrap.*—This term applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

II. PHYSICAL PROPERTIES AND TESTS.[1]

Tension Tests.

3. (*a*) The iron shall conform to the following requirements as to tensile properties:

[1] Committee A-2 on Wrought Iron, which prepared these specifications for presentation to the Society, desires to call attention to the fact that the vibration test has been omitted from the specifications. While recognizing its importance, the committee feels that the variations in the results obtained by this test are so great that it is not advisable to include such a requirement in the specifications until it has been carefully standardized. The committee means to institute further inquiries with the hope of reaching a sound basis for this test in the measurably near future.

Tensile strength, lb. per sq. in	49 000 – 53 000
Yield point, min., " "	0.6 tens. str.
Elongation in 8 in., min., per cent	30
Reduction of area, " "	48

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $1\frac{1}{2}$ in. per minute.

Bend Tests. 4. (*a*) *Cold-bend Tests.*—The test specimen shall bend cold through 180 deg. flat on itself in both directions without fracture on the outside of the bent portion.

(*b*) *Quench-bend Tests.*—The test specimen, when heated to a yellow heat and quenched at once in water the temperature of which is between 80° and 90° F., shall bend through 180 deg. flat on itself without fracture on the outside of the bent portion.

(*c*) *Nick-bend Tests.*—The test specimen, when nicked 25 per cent around with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter of the specimen, and broken, shall show a clean fiber entirely free from crystallization.

(*d*) Bend tests may be made by pressure or by blows.

Etch Tests.[1] 5. The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to have been rolled from a bloom or a boxpile, and to be free from steel.

Test Specimens. 6. All test specimens shall be of the full section of material as rolled.

Number of Tests. 7. (*a*) Bars of one size shall be sorted into lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof, and tested as specified in Sections 3 and 4; but only one of these bars shall be tested as specified in Section 5.

(*b*) If any test specimen from either of the bars originally selected to represent a lot of material, contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, one retest from a different bar will be allowed.

(*c*) When retests as specified in Paragraph (*b*) are not permitted, a reduction of 2 per cent in elongation and 3 per cent in

[1] A solution of two parts water, one part concentrated hydrochloric acid, and one part concentrated sulfuric acid is recommended for the etch test.

reduction of area from that specified in Section 3 (*a*) shall be allowed.

III. PERMISSIBLE VARIATIONS IN GAGE.

Permissible Variations.

8. The bars shall be truly round within 0.01 in., and shall not vary more than 0.005 in. above nor more than 0.01 in. below the specified size.

IV. FINISH.

Finish.

9. The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends, and evidences of being burnt.

V. MARKING.

Marking.

10. The bars shall be stamped or marked as designated by the purchaser.

VI. INSPECTION AND REJECTION.

Inspection.

11. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection.

12. (*a*) If either of the test bars selected to represent a lot does not conform to the requirements specified in Sections 3, 4, 5, and 6, the lot will be rejected.

(*b*) Bars which will not take a clean, sharp thread with dies in fair condition, or which develop defects in forging or machining, will be rejected, and the manufacturer shall be notified.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

REFINED WROUGHT-IRON BARS.

Serial Designation: A 41 – 13.

The specifications for this material are issued under the fixed designation A 41; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913.

I. MANUFACTURE.

Process.

1. Refined wrought-iron bars shall be made wholly from puddled iron, and may consist either of new muck-bar iron or a mixture of muck-bar iron and scrap, but shall be free from any admixture of steel.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

2. (*a*) The iron shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in. (See Sections 3 and 4)	48 000
Yield point, lb. per sq. in.	25 000
Elongation in 8 in., per cent (See Section 5)	22

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $1\frac{1}{2}$ in. per minute.

Permissible Variations in Tensile Strength.

3. Twenty per cent of the test specimens representing one size may show tensile strengths 1000 lb. per sq. in. under or

5000 lb. per sq. in. over that specified in Section 2; but no specimen shall show a tensile strength under 45,000 lb. per sq. in.

Modifications in Tensile Strength.

4. For flat bars which have to be reduced in width, a deduction of 1000 lb. per sq. in. from the tensile strength specified in Sections 2 and 3 shall be made.

Permissible Variations in Elongation.

5. Twenty per cent of the test specimens representing one size may show the following percentages of elongation in 8 in.:

ROUND BARS.

½ in. or over, tested as rolled	20 per cent
Under ½ in., " " "	16 "
Reduced by machining	18 "

FLAT BARS.

⅜ in. or over, tested as rolled	18 per cent
Under ⅜ in., " " "	16 "
Reduced by machining	16 "

Bend Tests.

6. (*a*) *Cold-bend Tests.*—Cold-bend tests will be made only on bars having a nominal area of 4 sq. in. or under, in which case the test specimen shall bend cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to twice the diameter or thickness of the specimen.

(*b*) *Hot-bend Tests.*—The test specimen, when heated to a temperature between 1700° and 1800° F., shall bend through 180 deg. without fracture on the outside of the bent portion, as follows: For round bars under 2 sq. in. in section, flat on itself; for round bars 2 sq. in. or over in section and for all flat bars, around a pin the diameter of which is equal to the diameter or thickness of the specimen.

(*c*) *Nick-bend Tests.*—The test specimen, when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60-deg. cutting edge, to a depth of not less than 8 nor more than 16 per cent of the diameter or thickness of the specimen, and broken, shall not show more than 10 per cent of the fractured surface to be crystallin.

(*d*) Bend tests may be made by pressure or by blows.

Etch Tests.[1]

7. The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to be free from steel.

Test Specimens.

8. (*a*) Tension and bend test specimens shall be of the full section of material as rolled, if possible. Otherwise, the specimens shall be machined from the material as rolled; the axis of the specimen shall be located at any point one-half the distance from the center to the surface of round bars, or from the center to the edge of flat bars, and shall be parallel to the axis of the bar.

TABLE I.—STANDARD LIMIT GAGES.

Nominal Diameter of Bars, in.	Large Size, +End, in.	Small Size, −End, in.	Total Variation, in.
1/4	0.2550	0.2450	0.010
5/16	0.3180	0.3070	0.011
3/8	0.3810	0.3690	0.012
7/16	0.4440	0.4310	0.013
1/2	0.5070	0.4930	0.014
9/16	0.5700	0.5550	0.015
5/8	0.6330	0.6170	0.016
3/4	0.7585	0.7415	0.017
7/8	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
1 1/8	1.1350	1.1150	0.020
1 1/4	1.2605	1.2395	0.021
1 3/8	1.3860	1.3640	0.022
1 1/2	1.5115	1.4885	0.023
1 5/8	1.6370	1.6130	0.024
1 3/4	1.7625	1.7375	0.025
1 7/8	1.8880	1.8620	0.026

Round bars 2 in. in diameter and over shall be rolled to nominal diameter.

(*b*) Etch test specimens shall be of the full section of material as rolled.

Number of Tests.

9. (*a*) All bars of one size shall be piled separately. One

[1] A solution of two parts water, one part concentrated hydrochloric acid, and one part concentrated sulfuric acid is recommended for the etch test.

bar from each 100 or fraction thereof will be selected at random and tested as specified.

(*b*) If any test specimen from the bar originally selected to represent a lot of material, contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, one retest from a different bar will be allowed.

III. PERMISSIBLE VARIATIONS IN GAGE.

Permissible Variations.

10. (*a*) Round bars shall conform to the standard limit gages adopted by the Master Car Builders' Association, as given in Table I.[1]

(*b*) The width or thickness of flat bars shall not vary more than 2 per cent from that specified.

IV. FINISH.

Finish.

11. The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends, and evidences of being burnt.

V. INSPECTION AND REJECTION.

Inspection.

12. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection.

13. All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified.

[1] Adopted by the Master Car Builders' Association in 1883 and revised in 1911. See *Proceedings*, Master Car Builders' Assoc., Vol. 49, Part 2, pp. 956–957 (1915).

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

IRON AND STEEL CHAIN.

Serial Designation: A 56–15.

The specifications for this material are issued under the fixed designation A 56; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1915.

Basis of Purchase.

1. (*a*) These specifications cover two classes of iron and one class of steel chain.

Class A, wrought-iron chain, is of the quality generally sold under the trade designation of "Crane Chain";

Class B, wrought-iron or steel chain, is of the quality generally sold under the trade designation of "Ordinary Coil Chain."

(*b*) The purposes for which these classes are generally used are as follows:

Class A, for slings, railway cranes, hoists and other places where a failure would imperil human life;

Class B, for ordinary service.

I. MATERIAL AND MANUFACTURE.

Process.

2. (*a*) *Class A, Iron Chain*, shall be manufactured from wrought iron which has been made wholly from puddled iron, free from any admixture of steel or scrap containing steel.

(*b*) *Class B, Iron Chain,* shall be manufactured from a grade of wrought iron conforming to the requirements of the Standard Specifications for Refined Wrought-Iron Bars (Serial Designation: A 41), of the American Society for Testing Materials.

(*c*) *Class B, Steel Chain,* shall be manufactured from steel made by the open-earth process, which shall be ductile and of satisfactory welding quality.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The wrought iron and steel used in the manufacture of chain of the respective classes referred to in this paragraph shall conform to the following requirements as to chemical composition:

	Class A.	Class B.	
	Iron.	Iron.	Steel.
Manganese	not over 0.10 per cent	....	....
Phosphorus	....	....	not over 0.05 per cent
Sulfur	....	....	" " 0.05 "

Check Analyses.

4. (*a*) Analyses may be made by the purchaser from finished chain, which shall conform to the requirements specified in Section 3.

(*b*) Drillings for analysis shall be taken with a drill the diameter of which is approximately one-half the diameter of the bar from which drillings are being taken, and the cuttings shall be taken through the bar from surface to surface.

III. PHYSICAL PROPERTIES AND TESTS.

Proof Tests.

5. (*a*) All chain shall be proof-tested by subjecting it to the loads shown in Table I, and when so tested it shall stand these loads without showing any defects.

(*b*) When requested, the manufacturer shall furnish a certificate of proof-test to the purchaser or his representative.

Tension Tests.

6. Samples from finished chain shall conform to the minimum requirements as to tensile properties specified in Table II, the elongation being determined in a gage length of from 12 to 18 in., to the nearest link.

7. Tension test specimens shall consist of a length not less than 2 ft. cut from the finished chain. **Test Specimens.**

8. One tension test shall be made to represent each 200 ft. or fraction thereof ordered. **Number of Tests.**

TABLE I.

Diameter of Bar, in.	Proof-Test Loads, lb.		
	Class A.	Class B.	
	Iron.	Iron.	Steel.
1/4	1 850	1 500	1 650
5/16	2 900	2 400	2 650
3/8	4 100	3 400	3 750
7/16	5 600	4 700	5 100
1/2	7 300	6 100	6 700
9/16	9 200	7 800	8 500
5/8	11 500	9 600	10 500
11/16	13 400	11 600	12 500
3/4	16 500	13 800	15 100
13/16	19 400	15 800	17 600
7/8	22 500	18 800	20 600
15/16	25 800	21 200	23 500
1	29 400	24 500	26 900
1 1/16	33 200	27 600	30 400
1 1/8	37 200	31 000	34 100
1 1/4	46 000	38 300	42 100
1 3/8	56 000	.....	.....
1 1/2	66 200	.....	.....
1 5/8	69 100	.....	.....
1 3/4	82 500	.....	.....
1 7/8	95 000	.....	.....
2	108 000	.....	.....

9. If the tension test fails to conform to the requirements specified in Section 6, two additional tension tests may be made, each of which shall meet the requirements of Section 6. **Retests.**

IV. STANDARD WEIGHTS AND DIMENSIONS.

Nominal Weights and Maximum Lengths.

10. (*a*) The nominal weights and maximum lengths of 100 links for chain of various sizes are given in Table III.

(*b*) The weight of the chain shall not vary more than 3

TABLE II.

Diameter of Bar, in.	Class A.		Class B.			
	Iron.		Iron.		Steel.	
	Breaking Load, lb.	Elongation, per cent.	Breaking Load, lb.	Elongation, per cent.	Breaking Load, lb.	Elongation, per cent.
1/4	3 700	15	3 000	10	3 300	12
5/16	5 800	15	4 800	10	5 300	12
3/8	8 200	15	6 800	10	7 500	12
7/16	11 200	15	9 400	10	10 200	12
1/2	14 600	15	12 200	10	13 400	12
9/16	18 400	15	15 600	10	17 000	12
5/8	23 000	15	19 200	10	21 000	12
11/16	26 800	15	23 200	10	25 000	12
3/4	33 000	15	27 600	10	30 200	12
13/16	38 800	15	31 600	10	35 200	12
7/8	45 000	15	37 600	10	41 200	12
15/16	51 600	15	42 400	10	47 000	12
1	58 800	15	49 000	10	53 800	12
1 1/16	66 400	15	55 200	10	60 800	12
1 1/8	74 400	15	62 000	10	68 200	12
1 1/4	92 000	15	76 600	10	84 200	12
1 3/8	112 000	15	.....	..	.....	..
1 1/2	132 400	15	.....	..	.....	..
1 5/8	138 200	15	.....	..	.....	..
1 3/4	165 000	15	.....	..	.....	..
1 7/8	190 000	15	.....	..	.....	..
2	216 000	15	.....	..	.....	..

per cent over nor more than 5 per cent under the nominal weight specified in Table III. Excess weight over the permissible variation of 3 per cent will not be paid for.

(*c*) The length shall be measured after the chain has been proof-tested, and shall be measured to the inside of the end links.

(*d*) In determining the length of the chain, a load not exceeding 10 per cent of the proof load specified in Table I shall be applied to take up the slack.

TABLE III.

Diameter of Bar, in.	Maximum Lengths of 100 Links, in.		Nominal Weight per 100 ft., lb.	
	Class A.	Class B.	Class A.	Class B.
$\frac{1}{4}$	88	102	83	75
$\frac{5}{16}$	100	114.7	125	110
$\frac{3}{8}$	113	125	175	165
$\frac{7}{16}$	125	137.5	220	205
$\frac{1}{2}$	140	150	280	265
$\frac{9}{16}$	150	166	360	325
$\frac{5}{8}$	170	176	450	425
$\frac{11}{16}$	185	195	540	520
$\frac{3}{4}$	200	213	625	610
$\frac{13}{16}$	213	225	745	725
$\frac{7}{8}$	225	238	850	810
$\frac{15}{16}$	238	250	960	925
1	250	263	1075	1025
$1\frac{1}{16}$	265	295	1240	1225
$1\frac{1}{8}$	280	325	1410	1350
$1\frac{1}{4}$	315	353.5	1750	1650
$1\frac{3}{8}$	355	....	2100	....
$1\frac{1}{2}$	390	....	2450	....
$1\frac{5}{8}$	425	....	2875	....
$1\frac{3}{4}$	475	....	3200	....
$1\frac{7}{8}$	525	....	3640	....
2	575	....	4200	....

V. WORKMANSHIP AND FINISH.

Workmanship and Finish.

11. (*a*) The chain shall be free from injurious defects and shall have a workmanlike finish. The diameter at the welds shall not be preceptibly less than the diameter of the bar and,

unless otherwise specified, shall not exceed the diameter of the bar by more than 25 per cent.

(*b*) Prior to testing and inspection the chain shall be free from paint or any other coating which would tend to conceal defects.

VI. INSPECTION AND REJECTION.

Inspection.

12. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*b*) The purchaser may make the tests to govern the acceptance of the material at his own laboratory, or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

13. Unless otherwise specified, any rejection based on tests made in accordance with Section 12 (*b*) shall be reported within five working days from receipt of samples.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR FOUNDRY PIG IRON.[1]

Serial Designation: A 43–09.

The specifications for this material are issued under the fixed designation A 43; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1909.

PERCENTAGES AND VARIATIONS.

In order that there may be uniformity in grading, the following percentages and variations shall be used.[2]

Silicon.		*Sulfur.*		*Total Carbon.*	
Per cent.	Code.	Per cent.	Code.	Per cent.	Code.
1.00	La	0.04	Sa	3.00	Ca
1.50	Le	0.05	Se	3.20	Ce
2.00	Li	0.06	Si	3.40	Ci
2.50	Lo	0.07	So	3.60	Co
3.00	Lu	0.08	Su	3.80	Cu
3.50	Ly	0.09	Sy		
		0.10	Sh		
(0.25 allowed either way.)		(Maximum.)		(Minimum.)	

[1] It is recommended that foundry pig iron be bought by analysis, and that when so bought these Standard Specifications be used.

[2] These specifications do not advise that all five elements be specified in all contracts for pig iron, but do recommend that when these elements are specified, the given percentages shall be used.

Manganese.		*Phosphorus.*	
Per cent.	Code.	Per cent.	Code.
0.20	Ma	0.20	Pa
0.40	Me	0.40	Pe
0.60	Mi	0.60	Pi
0.80	Mo	0.80	Po
1.00	Mu	1.00	Pu
1.25	My	1.25	Py
1.50	Mh	1.50	Ph
(0.20 allowed either way.)		(0.15 allowed either way.)	

Illustration of the use of above coding: The word Li-se-ca-mo-pi indicates

Sil.	Sul.	Carb.	Mang.	Phos.
2.00	0.05	3.00	0.80	0.60

with variations as allowed.

Percentages of any element specified half way between the above shall be designated by the addition of the letter X to the next lower symbol.

Example.—PeX indicates Phosphorus 0.50 with "allowed" variations (0.15) up and down.

In the case of phosphorus and manganese, the percentages may be used as maximum or minimum figures, but unless so specified they will be considered to include the variations above given.

SAMPLING AND ANALYSIS.

Each car load, or its equivalent, shall be considered as a unit in sampling.

One sample shall be taken to every four tons in the car, and shall be so chosen from different parts of the car as to represent as nearly as possible the average quality of the iron.

Drillings shall be taken so as to fairly represent the composition of the pig as cast.

An equal weight of the drillings from each pig shall be thoroughly mixed to make up the sample for analysis.

In case of dispute, the sampling and analysis shall be made by an independent chemist, mutually agreed upon, if practicable, at the time the contract is made.

It is recommended that the standard methods of the American Foundrymen's Association be used for analysis.

Gravimetric methods shall be used for the analysis of sulfur, unless otherwise specified in the contract.

The cost of re-sampling and re-analysis shall be borne by the party in error.

BASE OR QUOTING PRICE.

For market quotations, an iron of 2.00 per cent in silicon (with variations of 0.25 either way) and 0.05 per cent in sulfur (maximum) shall be taken as the base.

THE AMERICAN FOUNDRYMEN'S ASSOCIATION SUGGESTS THE FOLLOWING CLAUSES FOR THE PURPOSE OF ADJUSTING DISPUTES BETWEEN BUYER AND SELLER.

Base Table.—The following table may be filled out, and may become a part of the contract. "B," or Base, represents the price agreed upon for a pig iron running 2.00 per cent in silicon (with allowed variation of 0.25 either way) and under 0.05 per cent in sulfur; "C" is a constant differential to be determined at the time the contract is made.

This table is for settling any differences which may arise in filling a contract, as explained under penalties and allowances, and may be used to regulate the price of a grade of pig iron which the purchaser desires, and the seller agrees, to substitute for the one originally specified.

Silicon percentages allow 0.25 variation either way. Sulfur percentages are maximum.

Sulfur, per cent.	*Silicon, per cent.*									
	3.25	3.00	2.75	2.50	2.25	2.00	1.75	1.50	1.25	1.00
0.04....	B+6C	B+5C	B+4C	B+3C	B+2C	B+1C	B	B–1C	B–2C	B–3C
0.05....	B+5C	B+4C	B+3C	B+2C	B+1C	B	B–1C	B–2C	B–3C	B–4C
0.06....	B+4C	B+3C	B+2C	B+1C	B	B–1C	B–2C	B–3C	B–4C	B–5C
0.07....	B+3C	B+2C	B+1C	B	B–1C	B–2C	B–3C	B–4C	B–5C	B–6C
0.08....	B+2C	B+1C	B	B–1C	B–2C	B–3C	B–4C	B–5C	B–6C	B–7C
0.09....	B+1C	B	B–1C	B–2C	B–3C	B–4C	B–5C	B–6C	B–7C	B–8C
0.10....	B	B–1C	B–2C	B–3C	B–4C	B–5C	B–6C	B–7C	B–8C	B–9C

Penalties.—In case the iron, when delivered, does not conform to the specifications, the buyer shall have the option of either refusing the iron, or accepting it on the basis shown in the

above table, which must be filled out at the time the contract is made.

Allowances.—In case the furnace cannot, for any good reason, deliver the iron as specified at the time delivery is due, the purchaser may at his option accept any other analysis which the furnace can deliver, the price to be determined by the base table above, which must be filled out at the time the contract is made.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

CAST-IRON PIPE AND SPECIAL CASTINGS.

Serial Designation: A 44 – 04.

The specifications for this material are issued under the fixed designation A 44; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1904.

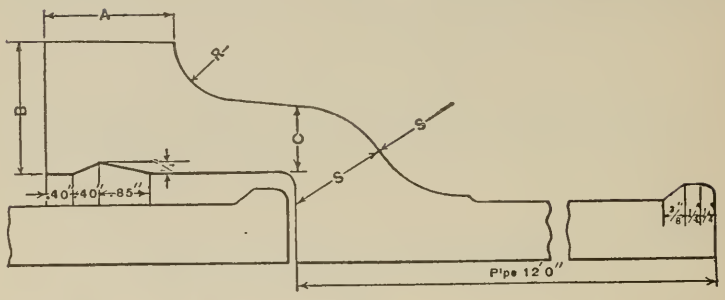
DESCRIPTION OF PIPES.

SECTION 1. The pipes shall be made with hub and spigot joints, and shall accurately conform to the dimensions given in Tables I and II. They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter. They shall be at least 12 ft. in length, exclusive of socket. For pipes of each size from 4 in. to 24 in., inclusive, there shall be two standards of outside diameter, and for pipes from 30 in. to 60 in., inclusive, there shall be four standards of outside diameter, as shown by Table II.

All pipes having the same outside diameter shall have the same inside diameter at both ends. The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of about 6 in. from each end of the pipe so as to obtain the required standard thickness and weight for each size and class of pipe.

Pipes whose standard thickness and weight are intermediate

TABLE I.—GENERAL DIMENSIONS OF PIPES.



Nominal Diam., in.	Classes.	Actual Outside Diam., in.	Diam. of Sockets.		Depth of Sockets.		A	B	C
			Pipe, in.	Special Castings, in.	Pipe, in.	Special Castings, in.			
4	A—B	4.80	5.60	5.70	3.50	4.00	1.5	1.30	0.65
4	C—D	5.00	5.80	5.70	3.50	4.00	1.5	1.30	0.65
6	A—B	6.90	7.70	7.80	3.50	4.00	1.5	1.40	0.70
6	C—D	7.10	7.90	7.80	3.50	4.00	1.5	1.40	0.70
8		9.05	9.85	10.00	4.00	4.00	1.5	1.50	0.75
8	C—D	9.30	10.10	10.00	4.00	4.00	1.5	1.50	0.75
10	A—B	11.10	11.90	12.10	4.00	4.00	1.5	1.50	0.75
10	C—D	11.40	12.20	12.10	4.00	4.00	1.5	1.60	0.80
12	A—B	13.20	14.00	14.20	4.00	4.00	1.5	1.60	0.80
12	C—D	13.50	14.30	14.20	4.00	4.00	1.5	1.70	0.85
14	A—B	15.30	16.10	16.10	4.00	4.00	1.5	1.70	0.85
14	C—D	15.65	16.45	16.45	4.00	4.00	1.5	1.80	0.90
16	A—B	17.40	18.40	18.40	4.00	4.00	1.75	1.80	0.90
16	C—	17.80	18.80	18.80	4.00	4.00	1.75	1.90	1.00
18	A—B	19.50	20.50	20.50	4.00	4.00	1.75	1.90	0.95
18	C—D	19.92	20.92	20.92	4.00	4.00	1.75	2.10	1.05
20	A—B	21.60	22.60	22.60	4.00	4.00	1.75	2.00	1.00
20	C—D	22.06	23.06	23.06	4.00	4.00	1.75	2.30	1.15
24	A—B	25.80	26.80	26.80	4.00	4.00	2.00	2.10	1.05
24	C—D	26.32	27.32	27.32	4.00	4.00	2.00	2.50	1.25
30	A	31.74	32.74	32.74	4.50	4.50	2.00	2.50	1.15
30	B	32.00	33.00	33.00	4.50	4.50	2.00	2.30	1.15
30	C	32.40	33.40	33.40	4.50	4.50	2.00	2.60	1.32
30	D	32.74	33.74	33.74	4.50	4.50	2.00	3.00	1.50
36	A	37.96	38.96	38.96	4.50	4.50	2.00	2.50	1.25
36	B	38.30	39.30	39.30	4.50	4.50	2.00	2.80	1.40
36	C	38.70	39.70	39.70	4.50	4.50	2.00	3.10	1.60
36	D	39.16	40.16	40.16	4.50	4.50	2.00	3.40	1.80
42	A	44.20	45.20	45.20	5.00	5.00	2.00	2.80	1.40
42	B	44.55	45.50	45.50	5.00	5.00	2.00	3.00	1.50
42	C	45.10	46.10	46.10	5.00	5.00	2.00	3.40	1.75
42	D	45.58	46.58	46.58	5.00	5.00	2.00	3.80	1.95
48	A	50.50	51.50	51.50	5.00	5.00	2.00	3.00	1.50

TABLE I.—(CONTINUED.)

Nominal Diam., in.	Classes.	Actual Outside Diam., in.	Diam. of Sockets.		Depth of Sockets.		A	B	C
			Pipe, in.	Special Castings, in.	Pipe in.	Special Castings, in.			
48	B	50.80	51.80	51.80	5.00	5 00	2.00	3.30	1.65
48	C	51.40	52.40	52.40	5.00	5.00	2.00	3.80	1.95
48	D	51.98	52.98	52.98	5.00	5.00	2.00	4 20	2.20
54	A	56.66	57.66	57.66	5.50	5.50	2.25	3.20	1.60
54	B	57.10	58.10	58.10	5.50	5.50	2.25	3.60	1.80
54	C	57.80	58.80	58.80	5.50	5.50	2.25	4.00	2.15
54	D	58.40	59.40	59.40	5.50	5.50	2.25	4.40	2.45
60	A	62.80	63.80	63.80	5.50	5.50	2.25	3.40	1.70
60	B	63.40	64.40	64.40	5.50	5.50	2.25	3.70	1.90
60	C	64.20	65.20	65.20	5.50	5.50	2.25	4.20	2.25
60	D	64.82	65.82	65.82	5.50	5.50	2.25	4.70	2.60

between the classes in Table II shall be made of the same outside diameter as the next heavier class. Pipes whose standard thickness and weight are less than shown by Table II shall be made of the same outside diameter as the Class A pipes, and pipes whose thickness and weight are more than shown by Table II shall be made of the same outside diameter as the Class D pipes.

For pipes 4 in. to 12 in., inclusive, one class of special castings shall be furnished, made from Class D pattern. Those having spigot ends shall have outside diameters of spigot ends midway between the two standards of outside diameter as shown by Table II, and shall be tapered back for a distance of 6 in. For pipes from 14 in. to 24 in., inclusive, two classes of special castings shall be furnished, Class B special castings with Classes A and B pipes, and Class D special castings with Classes C and D pipes, the former to be stamped "AB" and the latter to be stamped "CD." For pipes 30 in. to 60 in., inclusive, four classes of special castings shall be furnished, one for each class of pipe, and shall be stamped with the letter of the class to which they belong.

ALLOWABLE VARIATION IN DIAMETER OF PIPES AND SOCKETS.

SECTION 2. Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gages, and no pipe will be received which is defective in

TABLE II.—STANDARD THICKNESSES AND WEIGHTS OF CAST IRON PIPE.

Nominal Inside Diameter, in.	CLASS A. 100 FT. HEAD. 43 LB. PRESSURE.			CLASS B. 200 FT. HEAD. 86 LB. PRESSURE.			CLASS C. 300 FT. HEAD. 130 LB. PRESSURE.			CLASS D. 400 FT. HEAD. 173 LB. PRESSURE.			Nominal Inside Diameter, in.
	Thickness, in.	Weight per		Thickness, in.	Weight per		Thickness, in.	Weight per		Thickness, in.	Weight per		
		Foot.	Length.		Foot.	Length.		Foot.	Length.		Foot.	Length.	
4	0.42	20.0	240	0.45	21.7	260	0.48	23.3	280	0.52	25.0	300	4
6	0.44	30.8	370	0.48	33.3	400	0.51	35.8	430	0.55	38.3	460	6
8	0.46	42.9	515	0.51	47.5	570	0.56	52.1	625	0.60	55.8	670	8
10	0.50	57.1	685	0.57	63.8	765	0.62	70.8	850	0 68	76.7	920	10
12	0.54	72.5	870	0.62	82.1	985	0.68	91.7	1 100	0.75	100.0	1 200	12
14	0.57	89.6	1 075	0.66	102.5	1 230	0.74	116.7	1 400	0.82	129.2	1 550	14
16	0.60	108.3	1 300	0.70	125.0	1 500	0.80	143.8	1 725	0.89	158.3	1 900	16
18	0.64	129.2	1 550	0.75	150.0	1 800	0.87	175.0	2 100	0.96	191.7	2 300	18
20	0.67	150.0	1 800	0.80	175.0	2 100	0.92	208.3	2 500	1.03	229.2	2 750	20
24	0.76	204.2	2 450	0.89	233.3	2 800	1.04	279.2	3 350	1.16	306.7	3 680	24
30	0.88	291.7	3 500	1.03	333.3	4 000	1.20	400.0	4 800	1.37	450.0	5 400	30
36	0.99	391.7	4 700	1.15	454.2	5 450	1.36	545.8	6 550	1.58	625.0	7 500	36
42	1.10	512.5	6 150	1.28	591.7	7 100	1.54	716.7	8 600	1.78	825.0	9 900	42
48	1.26	666.7	8 000	1.42	750.0	9 000	1.71	908.3	10 900	1.96	1 050.0	12 600	48
54	1.35	800.0	9 600	1.55	933.3	11 200	1.90	1 141.7	13 700	2.23	1 341.7	16 100	54
60	1.39	916.7	11 000	1.67	1 104.2	13 250	2.00	1 341.7	16 100	2.38	1 583.3	19 000	60

The above weights are for 12 ft. laying lengths and standard sockets; proportionate allowance to be made for any variation therefrom.

joint room from any cause. The diameters of the sockets and the outside diameters of the bead ends of the pipes shall not vary from the standard dimensions by more than 0.06 in. for pipes 16 in. or less in diameter; 0.08 in. for 18-in., 20-in. and 24-in. pipes; 0.10 in. for 30-in., 36-in. and 42-in. pipes; 0.12 in. for 48-in. pipes; and 0.15 in. for 54-in. and 60-in. pipes.

ALLOWABLE VARIATION IN THICKNESS.

SECTION 3. For pipes whose standard thickness is less than 1 in., the thickness of metal in the body of the pipe shall not be more than 0.08 in. less than the standard thickness; and for pipes whose standard thickness is 1 in. or more, the variation shall not exceed 0.10 in., except that for spaces not exceeding 8 in. in length in any direction, variations from the standard thickness of 0.02 in. in excess of the allowance above given shall be permitted.

For special castings of standard patterns a variation of 50 per cent greater than allowed for straight pipe shall be permitted.

DEFECTIVE SPIGOTS MAY BE CUT.

SECTION 4. Defective spigot ends on pipes 12 in. or more in diameter may be cut off in a lathe, and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than 12 per cent of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than 11 ft. in length, exclusive of the socket.

In case the length of a pipe differs from 12 ft., the standard weight of the pipe given in Table II shall be modified in accordance therewith.

SPECIAL CASTINGS.

SECTION 5. All special castings shall be made in accordance with the cuts and the dimensions given in the table forming a part of these specifications.

The diameters of the sockets and the external diameters of the bead ends of the special castings shall not vary from the standard dimensions by more than 0.12 in. for castings 16 in. or less in diameter; 0.15 in. for 18-in., 20-in. and 24-in. pipes; 0.20 in. for 30-in., 36-in. and 42-in. pipes; and 0.24 in. for 48-in.,

54-in. and 60-in. pipes. These variations apply only to special castings made from standard patterns.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The manufacturer shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on plans and made of the best quality of mild steel, with hexagonal heads and nuts and sound, well-fitting threads.

MARKING.

SECTION 6. Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name. When cast especially to order, each pipe and special casting larger than 4 in. may also have cast upon it figures showing the year in which it was cast and a number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below, thus:

1901	1901	1901
1	2	3

etc., also any initials, not exceeding four, which may be required by the purchaser. The letters and figures shall be cast on the outside and shall be not less than 2 in. in length and $\frac{1}{8}$ in. in relief for pipes 8 in. in diameter and larger. For smaller sizes of pipes the letters may be 1 in. in length. The weight and the class letter shall be conspicuously painted in white on the inside of each pipe and special casting after the coating has become hard.

ALLOWABLE PERCENTAGE OF VARIATION IN WEIGHT.

SECTION 7. No pipe shall be accepted the weight of which shall be less than the standard weight by more than 5 per cent for pipes 16 in. or less in diameter, and 4 per cent for pipes more than 16 in. in diameter; and no excess above the standard weight of more than the given percentages for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same number of pieces of the given size and class by more than 2 per cent.

No special casting shall be accepted the weight of which shall be less than the standard weight by more than 10 per cent for pipes 12 in. or less in diameter, and 8 per cent for larger sizes, except that curves, Y-pieces and breeches pipe may be 12 per cent below the standard weight, and no excess above the standard weight of more than the above percentages for the several sizes will be paid for. These variations apply only to castings made from the standard patterns.

QUALITY OF IRON.

SECTION 8. All pipes and special castings shall be made of cast iron of good quality, and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace.

TESTS OF MATERIALS.

SECTION 9. Specimen bars of the metal used, each being 26 in. long by 2 in. wide and 1 in. thick, shall be made without charge as often as the engineer may direct, and, in default of definite instructions, the contractor shall make and test at least one bar from each heat or run of metal. The bars, when placed flat-wise upon supports 24 in. apart and loaded in the center, shall, for pipes 12 in. or less in diameter, support a load of 1900 lb. and show a deflection of not less than 0.30 in. before breaking; and for pipes of sizes larger than 12 in., they shall support a load of 2000 lb. and show a deflection of not less than 0.32 in. The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests.

CASTING OF PIPES.

SECTION 10. The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16 in. or less in diameter

shall be cast with the hub end up or down, as specified in the proposal. Pipes 18 in. or more in diameter shall be cast with the hub end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

QUALITY OF CASTINGS.

SECTION 11. The pipes and special castings shall be smooth, free from scales, lumps, blisters, sand holes and defects of every nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

CLEANING AND INSPECTION.

SECTION 12. All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

COATING.

SECTION 13. Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300° F. immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300° F. (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when

deemed necessary by the engineer. After being coated, the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be re-coated shall first be thoroughly scraped and cleaned.

HYDROSTATIC TEST.

SECTION 14. When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressure to which the different sizes and classes of pipes shall be subjected are as follows:

	20-In. Diameter and Larger, lb. per sq. in.	Less than 20-In. Diameter, lb. per sq. in.
Class A pipe	150	300
Class B pipe	200	300
Class C pipe	250	300
Class D pipe	300	300

WEIGHING.

SECTION 15. The pipes and special castings shall be weighed for payment under the supervision of the engineer after the application of the coal-tar pitch varnish. If desired by the engineer the pipes and special castings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Bids shall be submitted and a final settlement made up on the basis of a ton of 2000 lb.

CONTRACTOR TO FURNISH MEN AND MATERIALS.

SECTION 16. The contractor shall provide all tools, testing machines, materials and men necessary for the required testing, inspection and weighing at the foundry of the pipes and special castings; and, should the purchaser have no inspector at the works, the contractor shall, if required by the engineer, furnish a sworn statement that all of the tests have been made

as specified, this statement to contain the results of the tests upon the test bars.

POWER OF ENGINEER TO INSPECT.

SECTION 17. The engineer shall be at liberty at all times to inspect the material at the foundry, and the molding, casting and coating of the pipes and special castings. The forms, sizes, uniformity and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipes or other castings which are not in conformity with the specifications or drawings.

INSPECTOR TO REPORT.

SECTION 18. The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection.

CASTINGS TO BE DELIVERED SOUND AND PERFECT.

SECTION 19. All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipe or other castings which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered until the final completion and adjustment of the contract, provided, however, that the contractor shall not be held liable for pipes or special castings found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation or at any time after they receive the coating.

DEFINITION OF THE WORD "ENGINEER."

SECTION 20. Wherever the word "engineer" is used herein, it shall be understood to refer to the engineer or inspector acting for the purchaser and to his properly authorized agents, limited by the particular duties intrusted to them.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR CAST-IRON CAR WHEELS.

Serial Designation: A 46 – 05.

The specifications for this material are issued under the fixed designation A 46; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1905.

Chemical Properties

The wheels furnished under this specification must be made from the best materials, and in accordance with the best foundry methods. The following pattern analysis is given for information, as representing the chemical properties of a good cast-iron wheel. Successful wheels, varying in some of the constituents quite considerably from the figures given, may be made:

Total carbon	3.50 per cent
Graphitic carbon	2.90 "
Combined carbon	0.60 "
Silicon	0.70 "
Manganese	0.40 "
Phosphorus	0.50 "
Sulfur	0.08 "

1. Wheels will be inspected and tested at the place of manufacture.

2. All wheels must conform in general design and in measurements to drawings, which will be furnished, and any departure from the standard drawing must be by special permission in writing, and manufacturers wishing to deviate from the stand-

ard dimensions must submit duplicate drawings showing the proposed changes, which must be approved.

Drop Tests. 3. The following table gives data as to weight and tests of various kinds of wheels for different kinds of cars and service:

Wheel		33-in. diameter Freight and Passenger cars.			36-in. diameter.	
Kind of service		60 000 lb. capacity and less.	70 000 lb. capacity.	100 000 lb. capacity.	Passenger Cars.	Locomotive Tenders.
Number		1	2	3	4	5
Weight	Desired	600	650	700	700 lb.	750 lb.
	Variation	Two per cent either way.				
Height of drop, ft.		9	12	12	12	12
Number of blows		10	10	12	12	14

Marking. 4. Each wheel must have plainly cast on the outside plate the name of the maker and place of manufacture. Each wheel must also have cast on the inside double plate the date of casting and a serial foundry number. The manufacturer must also provide for the guarantee mark, if so required by the contract. No wheel bearing a duplicate number, or a number which has once been passed upon, will be considered. Numbers of wheels once rejected will remain unfilled. No wheel bearing an indistinct number or date, or any evidence of an altered or defaced number will be considered.

Measures. 5. All wheels offered for inspection must have been measured with a standard tape measure and must have the shrinkage number stenciled in plain figures on the inside of the wheel. The standard tape measure must correspond in form and construction to the "Wheel Circumference Measure" established by the Master Car Builders' Association in 1900. The nomenclature of that measure need not, however, be followed, it being sufficient if the graduating marks indicating tape sizes are $\frac{1}{8}$ in. apart. Any convenient method of showing the shrinkage or stencil number may be employed. Experience shows that standard tape measures elongate a little with use, and it is essential to have them frequently compared and rectified. When

ready for inspection, the wheels must be arranged in rows according to shrinkage numbers, all wheels of the same date being grouped together. Wheels bearing dates more than thirty days prior to the date of inspection will not be accepted for test, except by permission. For any single inspection and test only wheels having three consecutive shrinkage or stencil numbers will be considered. The manufacturer will, of course, decide what three shrinkage or stencil numbers he will submit in any given lot of 103 wheels offered, and the same three shrinkage or stencil numbers need not be offered each time.

Finish.

6. The body of the wheels must be smooth and free from slag and blowholes, and the hubs must be solid. Wheels will not be rejected because of drawing around the center core. The tread and throat of the wheels must be smooth, free from deep and irregular wrinkles, slag, sand wash, chill cracks or swollen rims, and be free from any evidence of hollow rims, and the throat and tread must be practically free from sweat.

Material and Chill.

7. Wheels tested must show soft, clean, gray iron, free from defects, such as holes containing slag or dirt more than $\frac{1}{4}$ in. in diameter, or clusters of such holes, honeycombing of iron in the hub, white iron in the plates or hub, or clear white iron around the anchors of chaplets at a greater distance than $\frac{1}{2}$ in. in any direction. The depth of the clear white iron must not exceed $\frac{7}{8}$ in. at the throat and 1 in. at the middle of the tread, nor must it be less than $\frac{3}{8}$ in. at the throat or any part of the tread. The blending of the white iron with the gray iron behind must be without any distinct line of demarcation, and the iron must not have a mottled appearance in any part of the wheel at a greater distance than $1\frac{5}{8}$ in. from the tread or throat. The depth of chill will be determined by inspection of the three test wheels described below, all test wheels being broken for this purpose, if necessary. If one only of the three test wheels fails in limits of chill, all the lot under test of the same shrinkage or stencil number will be rejected and the test will be regarded as finished so far as this lot of 103 wheels is concerned. The manufacturer may, however, offer the wheels of the other two shrinkage or stencil numbers, provided they are acceptable in other respects as constituents of another 103 wheels for a subsequent test. If two of the three test wheels fail in limits of chill, the wheels in the

lot of 103 of the same shrinkage or stencil number as these two wheels will be rejected, and, as before, the test will be regarded as finished so far as this lot of 103 wheels is concerned. The manufacturer may, however, offer the wheels of the third shrinkage or stencil number, provided they are acceptable in other respects, as constituents of another 103 wheels for a subsequent test. If all three test wheels fail in limits of chill, of course the whole hundred will be rejected.

Inspection and Shipping.

8. The manufacturer must notify when he is ready to ship not less than 100 wheels; must await the arrival of the inspector; must have a car, or cars, ready to be loaded with the wheels, and must furnish facilities and labor to enable the inspector to inspect, test, load and ship the wheels promptly. Wheels offered for inspection must not be covered with any substance which will hide defects.

9. A hundred or more wheels being ready for test, the inspector will make a list of the wheel numbers, at the same time examining each wheel for defects. Any wheels which fail to conform to specifications by reason of defects must be laid aside, and such wheels will not be accepted for shipment. As individual wheels are rejected, others of the proper shrinkage, or stencil number, may be offered to keep the number good.

Retaping.

10. The inspector will retape not less than 10 per cent of the wheels offered for test, and if he finds any showing wrong tape-marking, he will tape the whole lot and require them to be restenciled, at the same time having the old stencil marks obliterated. He will weigh and make check measurements of at least 10 per cent of the wheels offered for test, and if any of these wheels fail to conform to the specification, he will weigh and measure the whole lot, refusing to accept for shipment any wheels which fail in these respects.

Drop Tests.

11. Experience indicates that wheels with higher shrinkage or lower stencil numbers are more apt to fail on thermal test; more apt to fail on drop test, and more apt to exceed the maximum allowable chill than those with higher stencil or lower shrinkage numbers; while, on the other hand, wheels with higher stencil or lower shrinkage numbers are more apt to be deficient in chill. For each 103 wheels apparently acceptable, the inspector will select three wheels for test—one from each of the three shrinkage

or stencil numbers offered. One of these wheels chosen for this purpose by the inspector must be tested by drop test as follows: The wheel must be placed flange downward in an anvil block weighing not less than 1700 lb., set on rubble masonry 2 ft. deep and having three supports not more than 5 in. wide for the flange of the wheel to rest on. It must be struck centrally upon the hub by a weight of 200 lb., falling from a height as shown in the table in Section 3. The end of the falling weight must be flat, so as to strike fairly on the hub, and when by wear the bottom of the weight assumes a round or conical form, it must be replaced. The machine for making this test is shown on drawings which will be furnished. Should the wheel stand without breaking in two or more pieces, the number of blows, shown in the above table, the 100 wheels represented by it will be considered satisfactory as to this test. Should it fail, the whole hundred will be rejected.

Thermal Test.

12. The other two test wheels must be tested as follows: The wheels must be laid flange down in the sand, and a channelway $1\frac{1}{2}$ in. in width at the center of the tread and 4 in. deep must be molded with green sand around the wheel. The clean tread of the wheel must form one side of this channelway, and the clean flange must form as much of the bottom as its width will cover. The channelway must then be filled to the top from one ladle with molten cast iron, which must be poured directly into the channelway without previous cooling or stirring, and this iron must be so hot, when poured, that the ring which is formed when the metal is cold shall be solid or free from wrinkles or layers. Iron at this temperature will usually cut a hole at the point of impact with the flange. In order to avoid spitting during the pouring, the tread and inside of the flange during the thermal test should be covered with a coat of shellac; wheels which are wet or which have been exposed to snow or frost may be warmed sufficiently to dry them or remove the frost before testing, but under no circumstances must the thermal test be applied to a wheel that in any part feels warm to the hand. The time when pouring ceases must be noted, and two minutes later an examination of the wheel under test must be made. If the wheel is found broken in pieces, or if any crack in the plates extends through or into the tread, the test wheel will be regarded as having failed.

If both wheels stand, the whole hundred will be accepted as to this test. If both fail, the whole hundred will be rejected. If one only of the thermal test wheels fails, all of the lot under test of the same shrinkage or stencil number will be rejected, and the test will be regarded as finished, so far as this lot of wheels is concerned. The manufacturer may, however, offer the wheels of the other two shrinkage or stencil numbers, provided they are acceptable in other respects, as constituents of another 103 wheels for a subsequent test.

Storing and Shipping.

13. All wheels which pass inspection and test will be regarded as accepted, and may be either shipped or stored for future shipment, as arranged. It is desired that shipments should be, as far as possible, in lots of 100 wheels. In all cases the inspector must witness the shipment, and he must give, in his report the numbers of all wheels inspected and the disposition made of them.

Rejections.

14. Individual wheels will be considered to have failed and will not be accepted or further considered, which,

First.—Do not conform to standard design and measurement.

Second.—Are under or over weight.

Third.—Have the physical defects described in Section 6.

Rejections.

15. Each 103 wheels submitted for test will be considered to have failed and will not be accepted or considered further, if,

First.—The test wheels do not conform to Section 7, especially as to limits of white iron in the throat and tread and around chaplets.

Second.—One of the test wheels does not stand the drop test as described in Section 11.

Third.—Both of the two test wheels do not stand the thermal test as described in Section 12.

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STANDARD SPECIFICATIONS

FOR

MALLEABLE-IRON CASTINGS.[1]

Serial Designation: A 47 – 15.

The specifications for this material are issued under the fixed designation A 47; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1915.

I. MANUFACTURE.

Process. 1. The castings shall be made from iron melted in either an air furnace, open-hearth furnace or electric furnace.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 2. Tension test specimens specified in Section 5 shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	38 000
Elongation in 2 in., per cent	5

Transverse Tests. 3. Transverse test specimens specified in Section 5, tested with the cope side up on supports 12 in. apart, pressure being

[1] These specifications are intended for general use, and in particular for railroad malleable iron castings, for which purpose they will be designated when additional specifications for other classes of malleable iron castings shall be adopted.

applied at the center, shall conform to the following requirements as to transverse properties:

Thickness of Specimen, in.	Minimum Load Applied at Center lb.	Minimum Deflection at Center, in.
$\frac{1}{2}$	900	1.25
$\frac{5}{8}$	1 400	1.00
$\frac{3}{4}$	2 000	0.75

Special Tests.

4. In addition to the tension and transverse tests, the inspector representing the purchaser may satisfy himself of the suitability of the iron used for the castings by breaking a reasonable number of castings before annealing to examine for excessive mottling or graphite spots. In the case of castings of special design or importance, he may also require test lugs

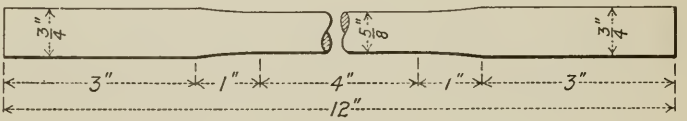

FIG. 1.

of a size proportional to the thickness of the casting, but not exceeding $\frac{5}{8}$ by $\frac{3}{4}$ in. in section. At least one of these lugs shall be left on the casting for final inspection.

Test Specimens.

5. (*a*) Tension test specimens shall be of the form and dimensions shown in Fig. 1. Transverse test specimens shall be 14 in. in length by 1 in. in width and either $\frac{1}{2}$, $\frac{5}{8}$ or $\frac{3}{4}$ in. in thickness. The thickness of the specimen selected shall be in proportion to the thickness of the casting which it represents.

(*b*) Two tension and two transverse test specimens shall be cast in each mold with risers of sufficient height at each end to secure sound bars. All specimens shall be cast without chills, and with ends perfectly free in the mold.

(*c*) Four molds shall be poured to represent each melt. When the entire melt is used for castings which are subject to these specifications, two molds shall be poured within five minutes after tapping into the first ladle, and two molds from

the last iron of the melt. When only part of the melt is required for such castings, two molds shall be poured from the first ladle of iron used and two molds after the required iron has been tapped.

(*d*) The molds shall be suitably stamped to identify the specimens.

The test specimens from one mold from the first and one mold from the last of the melt shall be annealed in the hottest part of the annealing oven, and the remaining specimens shall be annealed in the coldest part.

Number of Tests.

6. One tension and one transverse test specimen from each of the four molds representing a melt shall be selected for test. The remaining specimens shall be reserved, and shall be tested in case of failure to conform to the requirements specified.

Requirements.

7. If more than one tension or transverse test specimen from each of the two molds annealed in the two points in the oven specified in Section 5 (*d*) fails to meet the requirements as to tensile or transverse properties specified in Sections 2 and 3, the castings from that melt will be rejected.

III. WORKMANSHIP AND FINISH.

Workmanship.

8. The castings shall substantially conform to the sizes and shapes of the patterns, and shall be made in a workmanlike manner. A variation of $\frac{3}{32}$ in. per ft. will be permitted.

Finish.

9. The castings shall be free from blemishes, scale and shrinkage cracks.

IV. INSPECTION.

Inspection.

10. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

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STANDARD SPECIFICATIONS FOR GRAY-IRON CASTINGS.

Serial Designation: A 48 – 05.

The specifications for this material are issued under the fixed designation A 48; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1905.

Process of Manufacture.

1. Unless furnace iron is specified, all gray castings are understood to be made by the cupola process.

Chemical Properties.

2. The sulfur contents shall be as follows:

Light castings	not over 0.08 per cent.
Medium castings	" " 0.10 "
Heavy castings	" " 0.12 "

Classification.

3. In dividing castings into light, medium and heavy classes, the following standards have been adopted:

Castings having any section less than $\frac{1}{2}$ in. thick shall be known as *light castings.*

Castings in which no section is less than 2 in. thick shall be known as *heavy castings.*

Medium castings are those not included in the above classification.

Physical Properties.

4. *Transverse Test.*—The minimum breaking strength of the "Arbitration Bar" under transverse load shall be not under:

Light castings	2 500 lb.
Medium castings	2 900 "
Heavy castings	3 300 "

In no case shall the deflection be under 0.10 in.

Tension Test.—Where specified, this shall not run less than:

Light castings	18 000 lb. per sq. in.
Medium castings	21 000 " "
Heavy castings	24 000 " "

Arbitration Bar.

5. The quality of the iron going into castings under specification shall be determined by means of the "Arbitration Bar." This is a bar $1\frac{1}{4}$ in. in diameter and 15 in. long. It shall be prepared as stated further on and tested transversely. The tension test is not recommended, but in case it is called for, the bar as shown in Fig. 1, and turned up from any of the broken pieces of the transverse test shall, be used. The expense of the tension test shall fall on the purchaser.

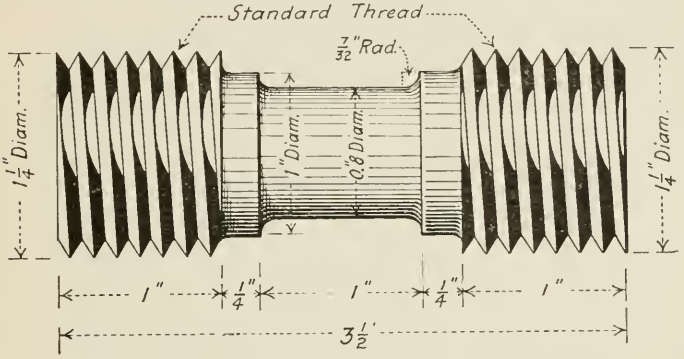

FIG. 1.—Tension Test Specimen.

Number of Test Bars.

6. Two sets of two bars shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. Where the heat exceeds 20 tons, an additional set of two bars shall be cast for each 20 tons or fraction thereof above this amount. In case of a change of mixture during the heat, one set of two bars shall also be cast for every mixture other than the regular one. Each set of two bars is to go into a single mold. The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

Method of Testing.

7. The transverse test shall be made on all the bars cast, with supports 12 in. apart, load applied at the middle, and the deflection at rupture noted. One bar of every two of each set made must fulfil the requirements to permit acceptance of the castings represented.

Mold for Test Bar.

8. The mold for the bars is shown in Fig. 2. The bottom of the bar is $\frac{1}{16}$ in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask is to be rammed up with green molding sand, a little damper than usual, well mixed and

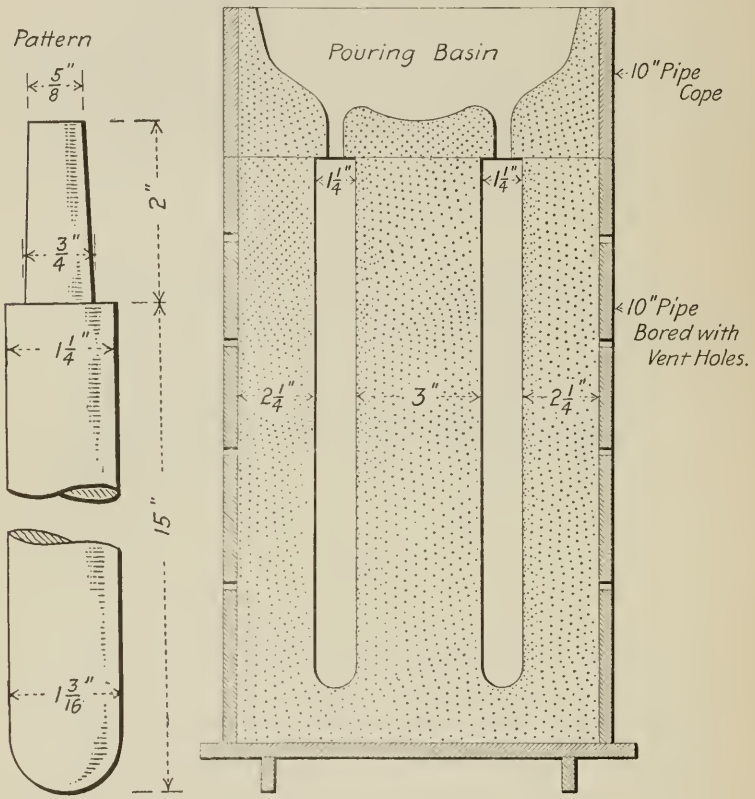

FIG. 2.—Mold for Arbitration Test Bar.

put through a No. 8 sieve, with a mixture of one to twelve bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled.

Speed of Testing.

9. The rate of application of the load shall be from 20 to 40 seconds for a deflection of 0.10 in.

10. Borings from the broken pieces of the "Arbitration Bar" shall be used for the sulfur determinations. One determination for each mold made shall be required. In case of dispute, the standards of the American Foundrymen's Association shall be used for comparison. **Samples for Analysis.**

11. Castings shall be true to pattern, free from cracks, flaws and excessive shrinkage. In other respects they shall conform to whatever points may be specially agreed upon. **Finish.**

12. The inspector shall have reasonable facilities afforded him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall, as far as possible, be made at the place of manufacture prior to shipment. **Inspection.**

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STANDARD SPECIFICATIONS

FOR

HARD-DRAWN COPPER WIRE.

Serial Designation: B 1 - 15.

The specifications for this material are issued under the fixed designation B 1; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1909; REVISED, 1911, 1913, 1915.

Material. 1. The material shall be copper of such quality and purity that, when drawn hard, it shall have the properties and characteristics herein required.

Shapes. 2. These specifications cover hard-drawn round wire, grooved trolley wire, and figure-eight trolley wire, as hereinafter described.

Finish. 3. (*a*) The wire, in all shapes, must be free from all imperfections not consistent with the best commercial practice.

(*b*) Necessary brazes in hard-drawn wire must be made in accordance with best commercial practice, and tests upon a section of wire containing a braze must show at least 95 per cent of the tensile strength of the unbrazed wire. Elongation tests are not to be made upon test sections including brazes.

Packages. 4. (*a*) Package sizes for round wire shall be agreed upon in the placing of individual orders; standard packages of grooved trolley wire shall be shipments upon reels holding about 2500 lb. each.

(*b*) The wire shall be protected against damage in ordinary handling and shipping.

5. For the purpose of calculating weights, cross-sections, etc., the specific gravity of copper shall be taken as 8.89 at 20° C. Specific Gravity.

6. All testing and inspection shall be made at the place of manufacture. The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to enable him to satisfy himself that the material conforms to the requirements of these specifications. Inspection.

HARD-DRAWN ROUND WIRE.

7. (*a*) Size shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals; that is, in mils. Dimensions and Permissible Variations.

(*b*) Wire is expected to be accurate in diameter; permissible variations from nominal diameter shall be:

For wire 0.100 in. in diameter and larger, one per cent over or under;

For wire less than 0.100 in. in diameter, one mil over or under.

(*c*) Each coil is to be gaged at three places, one near each end, and one approximately at the middle; the coil may be rejected if, two points being within the accepted limits, the third point is off gage more than 2 per cent in the case of wire 0.064 in. in diameter and larger, or more than 3 per cent in the case of wire less than 0.064 in. in diameter.

8. Wire shall be so drawn that its tensile strength and elongation shall be at least equal to the value stated in Table I. Tensile tests shall be made upon fair samples, and the elongation of wire larger in diameter that 0.204 in. shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The elongation of wire 0.204 in. in diameter and smaller shall be determined by measurements made between the jaws of the testing machine. The zero length shall be the distance between the jaws when a load equal to ten per cent of the required ultimate breaking strength shall have been applied, and the final length shall be the distance between the jaws at the time of rupture. The zero length shall be as near 60 in. as Physical Test.

possible. The fracture shall be between the bench marks in the case of wire larger than 0.204 in. in diameter and between the jaws in the case of smaller wire, and not closer than 1 in. to either bench mark or jaw. If upon testing a sample from any coil of wire, the results are found to be below the values stated in the table, tests upon two additional samples shall be made, and the average of the three tests shall determine acceptance or rejection of the coil. For wire whose nominal diameter is between listed sizes, the requirements shall be those of the next larger size included in the table.

TABLE I.

Diameter, in.	Area, circular mils.	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent.
0.460	211 600	49 000	3.75
0.410	168 100	51 000	3.25
0.365	133 225	52 800	2.80
0.325	105 625	54 500	2.40
0.289	83 520	56 100	2.17
0.258	66 565	57 600	1.98
0.229	52 440	59 000	1.79
			in 60 in.
0.204	41 615	60 100	1.24
0.182	33 125	61 200	1.18
0.165	27 225	62 000	1.14
0.162	26 245	62 100	1.14
0.144	20 735	63 000	1.09
0.134	17 956	63 400	1.07
0.128	16 385	63 700	1.06
0.114	12 995	64 300	1.02
0.104	10 815	64 800	1.00
0.102	10 404	64 900	1.00
0.092	8 464	65 400	0.97
0.091	8 281	65 400	0.97
0.081	6 561	65 700	0.95
0.080	6 400	65 700	0.94
0.072	5 184	65 900	0.92
0.065	4 225	66 200	0.91
0.064	4 096	66 200	0.90
0.057	3 249	66 400	0.89
0.051	2 601	66 600	0.87
0.045	2 025	66 800	0.86
0.040	1 600	67 000	0.85

9. Electric resistivity shall be determined upon fair samples by resistance measurements at a temperature of 20° C. (68° F.). **Electric Resistivity.**

The wire shall not exceed the following limits:

For diameters 0.460 in. to 0.325 in., 900.77 lb. per mile-ohm at 20° C.;

For diameters 0.324 in. to 0.040 in., 910.15 lb. per mile-ohm at 20° C.

GROOVED TROLLEY WIRE.

10. Standard sections shall be those known as the "American Standard Grooved Trolley Wire Sections," the shape and dimensions of which are as shown in Fig. 1. **Sections.**

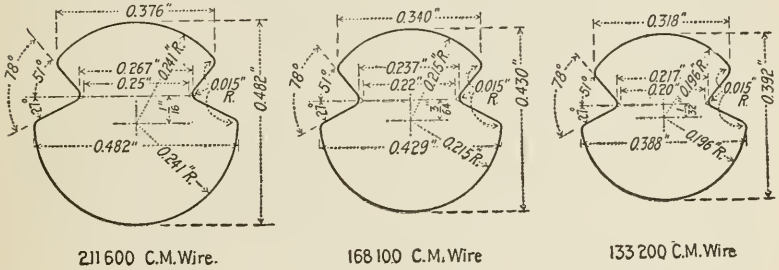

FIG. 1.

11. (*a*) Size shall be expressed as the area of cross-section in circular mils, the standard sizes being as follows: **Dimensions and Permissible Variations.**

211,600	circular	mils,	weighing	3,386	lb.	per	mile.
168,100	"	"	"	2,690	"	"	"
133,200	"	"	"	2,132	"	"	"

(*b*) Grooved trolley wire may vary 4 per cent over or under in weight per unit length from standard, as determined from the nominal cross-section.

12. The physical tests shall be made in the same manner as those upon round wire. The tensile strength of grooved wire shall be at least 95 per cent of that required for round wire of the same sectional area; the elongation shall be the same as that required for round wire of the same sectional area. **Physical Tests.**

Electric Resistivity.

13. The requirements for electric resistivity shall be the same as those for round wire of the same sectional area.

FIGURE-EIGHT TROLLEY WIRE.

Sections.

14. Standard sections of figure-eight trolley wire shall be as shown in Fig. 2.

Requirements.

15. The requirements for weight, physical properties, and electric resistivity of figure-eight trolley wire shall be the same as for the same sizes of grooved trolley wire.

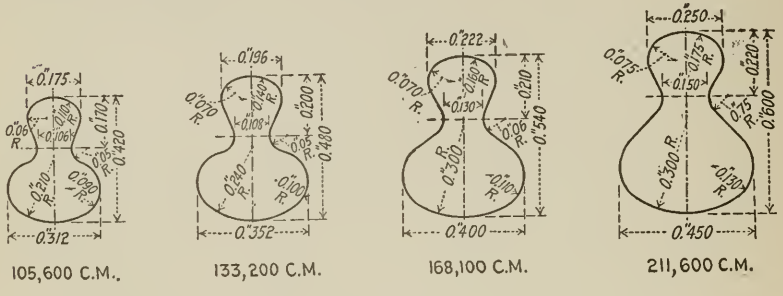

FIG. 2.

EXPLANATORY NOTES ON STANDARD SPECIFICATIONS FOR HARD-DRAWN COPPER WIRE.

5. The specific gravity of copper was formerly standardized in these specifications at 8.90. The value has been changed to 8.89, since that is the value adopted as standard by the American Institute of Electrical Engineers and the International Electro-Technical Commission.

7. (*a*) The use of arbitrary gage numbers to express dimensions cannot be too strongly condemned. There are many such gages in existence, and confusion is to be expected unless the particular gage to be used is specified. Many of the gages have their dimensions stated in absurd figures, such as 0.090742 in., when it is not especially easy to measure dimensions in the fourth decimal place by workshop tools. Definite diameters in measurable units are evidently preferable.

8. Many other physical tests than those provided in these

specifications are included in existing specifications. The reasons for the omission of some of the more common are given as follows:

Twist Tests.—The wire is sometimes required to permit twisting through a stated number of revolutions before breaking. The results are so easily influenced by temperature, speed of rotation, method of gripping, and other variables not easily defined or controlled, that the test is at least of doubtful value. It is the opinion of the committee[1] that it is impractical to so define the conditions of the test that a twist test can be made definite and reliable; hence there is no warrant for its inclusion in specifications.

Wrap Tests.—Wire is sometimes required to permit tight wrapping about a wire of its own diameter, unwrapping and again re-wrapping. It is obvious that the making of a test of this kind with wire that is already hard-drawn is exceedingly difficult. Every one who has tried to break off a piece of tough wire by bending it back and forth between the fingers, knows how hard it is to confine the bend to one place, because of the hardening action of the previous bends. Hard wire which has been wrapped around a wire of small diameter is hardened still more and it is almost impossible to straighten the wire, let alone re-coil it in the opposite direction. In the opinion of the committee, it is inadvisable to include a test which at best is so indefinite as a wrap test. Furthermore, it is the opinion of the committee that wire which will meet the physical tests included in these specifications will meet any properly made twist or wrap test that would reasonably be required.

Since the adoption of the Standard Specifications for Hard-Drawn Copper Wire, proposed in 1909, the committee has very carefully considered the matter of twist and wrap tests, and it is their final opinion that while there might be some possible reason for requiring that wire shall stand wrapping around a wire of equal diameter, there can be no good reason for including in specifications the requirement that it shall stand unwrapping and re-wrapping, because such a test is indefinite and cannot be made otherwise. It is almost physically impossible to unwrap and re-wrap hard-drawn wire about a wire of its own diameter. With respect to twist tests, the committee has nothing to add to

[1]Committee B-1 on Standard Specifications for Copper Wire.

the statement already on record, condemning this character of test.

Elastic Limit.—During the tension test on wire, there is seldom to be observed any definite drop of the beam or increase in the rate of elongation, corresponding to the yield point commonly observed in testing steel. The only way in which the elastic limit of hard wire may be determined is by the actual plotting of the elastic curve from extensometer readings. Even such tests are difficult of interpretation, because the wire when available for tests is usually curved, due to its having been put up in a coil. There are little sets observable before the true elastic limit has been reached, owing to the fact that one side of the wire, having been stretched in coiling, is really a little harder that the other side, and the pull is, therefore, not even. Considering the difficulty of making the test and the uncertainty of the results obtained, it is the opinion of the committee that it would be inadvisable to include an elastic limit test in these specifications. It is evident that if the designing engineer requires a knowledge of the location of the elastic limit, for purposes of calculation in designing, such data can be obtained by special tests on representative sizes of wire, which will fix the relation of the elastic limit to the ultimate strength for all wire which is properly made.

Tests carefully made by members of the committee show that the elastic limit of hard-drawn copper wire from sizes 0.460 to 0.325 in., inclusive, averages 55 per cent of the ultimate tensile strength required in these specifications, with a minimum value of 50 per cent; for sizes 0.324 to 0.040 in., inclusive, it averages 60 per cent of the ultimate tensile strength required in these specifications, with a minimum value of 55 per cent. This statement of experience is based on the definition of elastic limit as "that point on the elastic curve beyond which the ratio of stress to strain ceases to be constant."

9. *Conductivity.*—Electric conductivity was formerly expressed as a percentage on the basis of a determination made by Matthiessen about 1865, of the electric resistivity of supposedly pure copper. Since that time the methods of refining copper have advanced, so that it is not uncommon to find copper of over 100 per cent conductivity on the Matthiessen basis.

There has until recently not been international agreement on the electric resistivity of copper to be considered the standard for the expression of conductivity. While international agreement upon the value 0.15328 ohms per meter-gram at 20° C. for the resistivity of copper equal to 100 per cent conductivity was reached by the International Electro-Technical Commission in 1913, it has been deemed preferable to express the requirements in standard specifications in the terms of quantities directly measurable, rather than by reference to some quantity whose standard value is the subject of agreement only. The use of the arbitrary term "conductivity" has no more warrant than the employment of arbitrary gage numbers. Therefore, in these specifications the requirements are stated as the maximum rejection limits to the resistivity.

For the convenience of those who are accustomed to express resistivity in any of the several more or less common units, the following table of equivalents has been prepared, giving the resistivity of copper at 20° C.:

900.77 lb. per mile-ohm is equal to:

0.15775 ohms per meter-gram,
1.7745 microhms per centimeter-cube,
0.69863 microhms per inch-cube,
10.674 ohms per mil-foot.

910.15 lb. per mile-ohm is equal to:

0.15940 ohms per meter-gram,
1.7930 michroms per centimeter-cube,
0.70590 microhms per inch-cube,
10.785 ohms per mil-foot.

10. It is obvious that the simplest designation of irregular shapes of similar outline is by sectional area, and the most commonly used unit among electrical engineers is the circular mil. Therefore, while the sizes of grooved trolley wire regularly used are generally known by B & S gage number, corresponding to their sectional area, it has been deemed advisable by the committee to list these sizes, in specifications, by their sectional area expressed in circular mils. The three sizes which are most

extensively used commercially are the only ones listed; a fourth size is but little used, and the use is growing less.

11. The only way in which gage variations are easily determinable in irregular shapes is by recourse to weights of standard lengths, and this has been the method adopted in the specifications.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

BARE CONCENTRIC-LAY COPPER CABLE: HARD, MEDIUM-HARD, OR SOFT.

Serial Designation: B 8 – 16.

The specifications for this material are issued under the fixed designation B 8; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1916.

I. MANUFACTURE.

Products Covered.

1. (*a*) These specifications cover bare concentric-lay cables made from round copper wires laid helically around a central core in one or more layers. The central core shall be made of wire having the same quality and temper as the concentric layers, unless otherwise especially provided for in separate specifications governing the individual case.

Classes.

(*b*) The purposes for which the several classes of concentric-lay cables are generally used are as follows:

Class A, for bare, weatherproof, slow-burning, and slow-burning weatherproof cable for aerial use.

Class B, for various insulated cable, such as rubber, paper, varnished cloth, etc.

Class C, for cable where greater flexibility is required than in Class B.

Requirements of Wires.

2. The copper wires entering into the construction of standard concentric-lay cable shall, before stranding, meet all

the requirements of that one of the Standard Specifications of the American Society for Testing Materials for Hard-Drawn, Medium Hard-Drawn, or Soft or Annealed Copper Wire (Serial Designations: B 1, B 2, or B 3), which applies.

Brazes.

3. Brazes may be made in the wire when finished and ready for cabling. Such brazes shall be made in accordance with the best commercial practice. No brazes in cable made from hard, or medium hard-drawn copper wire may be closer together than 50 ft.

Pitch and Lay.

4. The pitch of standard cable shall not be less than 12 nor more than 16 diameters of the cable, and the lay may be right or left-handed, unless one direction of lay is specified by the purchaser.

II. PHYSICAL PROPERTIES AND TESTS.

Testing.

5. Tests for the physical and electrical properties of the wires composing the cables may be made before, but not after, stranding. Experience indicates that the tensile strength of concentric-lay copper cable of standard pitch is at least 90 per cent of the total strength required of the wires forming the cable.

Weights and Area.

6. For the purpose of calculating weights, cross-sections, etc., the specific gravity of copper shall be taken as 8.89 at 20° C. The resistance and mass of a stranded conductor are greater than in a solid conductor of the same cross-sectional area, depending on the lay (that is, the pitch of the twist of the wires). Two per cent shall be taken as the standard increment of resistance and of mass. In cases where the lay is definitely known, the increment shall be calculated and not assumed.

Variation in Area.

7. The area of cross-section of the completed cable shall not be more than 2 per cent below the area specified, as determined by weight.

Construction.

8. The area of cross-section, number and diameter of wires, in standard cable Classes A, B, and C, shall be as specified in Table I.

III. PACKING AND SHIPPING.

Packing and Shipping.

9. (*a*) Package sizes for cable shall be agreed upon in the placing of individual orders.

(*b*) The cable shall be protected against damage in ordinary handling and transportation.

TABLE I.

Area of Cross-Section, circular mils.	Approximate A. W. G. or B. & S. Gage Sizes.	CLASS A.		CLASS B.		CLASS C.	
		Number of Wires.	Diameter of Wires, mils.	Number of Wires.	Diameter of Wires, mils.	Number of Wires.	Diameter of Wires, mils.
2 000 000	....	91	148.2	127	125.5	169	108.8
1 900 000	....	91	144.5	127	122.3	169	106.0
1 800 000	....	91	140.6	127	119.1	169	103.2
1 700 000	....	91	136.6	127	115.7	169	100.3
1 600 000	....	91	132.6	127	112.2	169	97.3
1 500 000	....	61	156.8	91	128.4	127	108.7
1 400 000	....	61	151.5	91	124.0	127	105.0
1 300 000	....	61	146.0	91	119.5	127	101.2
1 250 000	....	61	143.2	91	117.2	127	99.2
1 200 000	....	61	140.3	91	114.8	127	97.2
1 100 000	....	61	134.3	91	109.9	127	93.1
1 000 000	....	61	128.0	61	128.0	91	104.8
950 000	....	61	124.8	61	124.8	91	102.2
900 000	....	61	121.5	61	121.5	91	99.4
850 000	....	61	118.0	61	118.0	91	96.6
800 000	....	61	114.5	61	114.5	91	93.8
750 000	....	61	110.9	61	110.9	91	90.8
700 000	....	61	107.1	61	107.1	91	87.7
650 000	....	61	103.2	61	103.2	91	84.5
600 000	....	37	127.3	61	99.2	91	81.2
550 000	....	37	121.9	61	95.0	91	77.7
500 000	....	37	116.2	37	116.2	61	90.5
450 000	....	37	110.3	37	110.3	61	85.9
400 000	....	19	145.1	37	104.0	61	81.0
350 000	....	19	135.7	37	97.3	61	75.7
300 000	....	19	125.7	37	90.0	61	70.1
250 000	....	19	114.7	37	82.2	61	64.0
212 000	4/0	7-19	173.9-105.5	19	105.5	37-61	75.6-58.9
168 000	3/0	7-19	155.0-94.0	19	94.0	37-61	67.3-52.5
133 000	2/0	7	138.0	19	83.7	37	60.0
106 000	1/0	7	122.8	19	74.5	37	53.4
83 750	1	7	109.3	19	66.4	37	47.6
66 400	2	7	97.4	7	97.4	19	59.1
52 600	3	7	86.7	7	86.7	19	52.6
41 700	4	7	77.2	7	77.2	19	46.9
33 100	5	7	68.8	7	68.8	19	41.7
26 300	6	7	61.2	7	61.2	19	37.2
20 800	7	7	54.5	7	54.5	19	33.1
16 500	8	7	48.6	7	48.6	19	29.5

NOTE.—Class A cable, sizes 4/0 and 3/0, is usually 7-strand when bare and 19-strand when weatherproof, etc.

IV. INSPECTION.

Inspection.

10. (*a*) All testing and inspection, both of individual wires entering into the construction of the cable, and of the completed cable, shall be made at the place of manufacture. Tests on individual wires shall be made on samples taken before cabling, and not on wires removed from the completed cable.

(*b*) The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material conforms to the requirements of these specifications.

V. DEFINITION OF TERMS.

Concentric-Lay Cable.

11. *Concentric-Lay Cable.*—A single conductor cable composed of a central core surrounded by one or more layers of helically laid wires.

Lay.

12. *Lay.*—The lay of a cable is the length expressed in inches for each complete turn of the wire around the axis, measured along its axis.

Direction of Lay.

13. *Direction of Lay.*—The direction of lay is the lateral direction in which the strands of a cable run over the top of the cable as they recede from an observer looking along the axis of the cable.

EXPLANATORY NOTES.

1. *Classes of Cable.*—These specifications have been drawn to cover cables made from hard-drawn, medium hard-drawn, and soft copper wire, since the manufacturing of cables from the various classes of wire is similar, and the physical properties of the cable depend upon, and are usually expressed in, terms of those of the class of wire employed.

2. *Physical Properties.*—The accurate testing of cable for its physical properties is practically impossible in commercial laboratories. In order to do this, it is necessary to use long lengths and hold the samples in such a way that the wires shall all be in equal tension. Otherwise the strength will be considerably below the actual strength of the cable. A much more accurate idea of the quality of the cable may be obtained by testing the individual wires before cabling than by attempting tests of the physical properties of the finished cable.

Wires unlaid from cable will manifestly have different physical and electrical properties from those of the wire when prepared for cabling, on account of the deformation brought about by laying and again straightening for test.

3. *Stranding Table.*—The stranding table covers present practice. Class A covers the usual bare and weatherproof con-

struction. Class B is the same as adopted by the Standards Committee of the American Institute of Electrical Engineers, and is given in the Bureau of Standards Circular No. 31, Table XII.

In Class C the figures are those of the Bureau of Standards, Circular No. 31, Table XII, with additions to cover well-established practice. There is need for a table to cover extra-flexible stranding from soft wire, but there are differences of opinion in regard to what should become standard practice. The Standards Committee of the A. I. E. E. have this matter under consideration, and it has seemed best not to attempt to include figures for extra-flexible stranding in this specification. The stranding table will necessarily be the subject of revision which will be undertaken in cooperation with the Standards Committee of the A. I. E. E.

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STANDARD SPECIFICATIONS

FOR

HIGH-STRENGTH BRONZE TROLLEY WIRE, ROUND AND GROOVED: 40 AND 65-PER-CENT CONDUCTIVITY.

Serial Designation: B 9 – 16.

The specifications for this material are issued under the fixed designation B 9; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1916.

I. MANUFACTURE.

Shapes. 1. These specifications cover round and grooved bronze trolley wire.

Material. 2. The material used shall be bronze of such nature and composition as to secure, by proper treatment, the qualities hereinafter specified for the finished wire. Bronze of two qualities may be required—one to have a conductivity of 40 per cent, and the other a conductivity of 65 per cent.

Brazes. 3. Necessary brazes in trolley wire shall be made in accordance with the best commercial practice, and tests upon a section of wire containing a braze shall show at least 95 per cent of the tensile strength of the unbrazed wire.

Elongation tests shall not be made on test sections including brazes.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

4. (*a*) Round wire shall conform to the requirements as to tensile properties specified in Table I.

(*b*) The tensile strength of grooved wire shall be at least 95 per cent of that required for round wire of the same sectional area; the elongation of grooved wire shall be the same as that required for round wire of the same sectional area.

Tension Test Specimens.

5. Tension tests shall be made upon fair samples, and the elongation of the wire shall be determined as permanent increase in length, due to the breaking of the wire in tension, measured between bench marks placed upon the wire originally 10 in. apart. The fracture shall be between the bench marks, and not closer than 1 in. to either mark. If, upon testing a sample from any coil or reel of wire, the results are found to be below the value stated in the table, tests on two additional samples shall be made, and the average of the three tests shall determine the acceptance or rejection of the coil or reel.

TABLE I.

Diameter, in.	Area, circular mils.	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent.
40-PER-CENT CONDUCTIVITY BRONZE.			
0.460	211 600	69 200	3.00
0.410	168 100	69 700	3.00
0.365	133 225	71 700	2.50
0.325	105 625	77 100	2.25
65-PER-CENT CONDUCTIVITY BRONZE.			
0.460	211 600	59 300	3.00
0.410	168 100	59 800	3.00
0.365	133 225	61 600	2.50
0.325	105 625	66 300	2.25

Conductivity.

6. (*a*) Round wire, known as "40-per-cent Conductivity," shall have a conductivity of not less than 40 per cent, figured according to the International Annealed Copper Standard, which is 0.15328 ohms per meter-gram at 20° C.

Round wire, known as "65-per-cent Conductivity," shall have a conductivity of not less than 65 per cent, figured according to the same standard.

(*b*) The requirements for conductivity of grooved wire shall be the same as those for round wire of the same sectional area.

III. STANDARD SIZES AND DIMENSIONS.

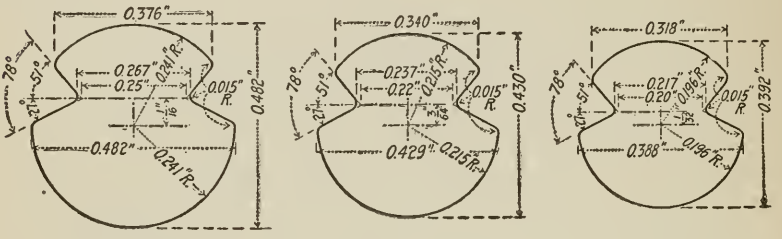
Dimensions and Permissible Variations of Round Wire.

7. (*a*) The size of round wire shall be expressed as the diameter of the wire in decimal fractions of an inch, using not more than three places of decimals, that is, in mils.

(*b*) Round wire is expected to be accurate in diameter. Variations of one per cent over or under nominal diameter shall be permissible.

Standard Sections, Dimensions and Permissible Variations of Grooved Wire.

8. (*a*) Standard sections of grooved trolley wire shall be those known as the "American Standard Grooved Trolley Wire Sections," the shape and dimensions of which are shown in Fig. 1.



211600 C.M. Wire. 168100 C.M. Wire 133200 C.M. Wire

FIG. 1.

(*b*) The size of grooved wire shall be expressed as the area of cross-section in circular mils, the standard sizes being as follows:

211,600	circular mils,	weighing.....	3,386	lb.	per mile
168,100	"	" "	2,690	"	" "
133,200	"	" "	2,132	"	" "

(*c*) Grooved trolley wire may vary 4 per cent over or under in weight per unit length from standard as determined from the nominal cross-section.

IV. WORKMANSHIP AND FINISH.

Finish.

9. The wire shall be free from all imperfections not consistent with the best commercial practice.

V. PACKING AND SHIPPING.

Packing and Shipping.

10. All wire shall be furnished on substantial reels, suitable for the weight of the wire handled, and shall be protected against damage in ordinary handling and transportation. The length or weight of wire to be wound upon reels shall be agreed upon in placing individual orders.

VI. INSPECTION.

Inspection.

11. (*a*) All testing and inspection shall be made at the place of manufacture.

(*b*) The manufacturer shall afford the inspector representing the purchaser all reasonable facilities to satisfy him that the material conforms to the requirements of these specifications.

AMERICAN SOCIETY FOR TESTING MATERIALS

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT.[1]

These specifications are the result of several years' work of a special committee representing a United States Government Departmental Committee, the Board of Direction of the American Society of Civil Engineers, and Committee C-1 on Cement of the American Society for Testing Materials.

Serial Designation: C 9 – 17.

The specifications and tests for this material are issued under the fixed designation C 9; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1904; REVISED, 1908, 1909, 1916.

SPECIFICATIONS.

Definition.

1. Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion, an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

I. CHEMICAL PROPERTIES.

Chemical Limits.

2. The following limits shall not be exceeded:

Loss on ignition, per cent	4.00
Insoluble residue, per cent	0.85
Sulfuric anhydride (SO_3), per cent	2.00
Magnesia (MgO), per cent	5.00

[1] These specifications and tests were adopted by letter ballot of the Society on September 1, 1916, with the understanding that they will not become effective till January 1, 1917.

II. PHYSICAL PROPERTIES.

Specific Gravity. 3. The specific gravity of cement shall be not less than 3.10 (3.07 for white Portland cement). Should the test of cement as received fall below this requirement a second test may be made upon an ignited sample. The specific gravity test will not be made unless specifically ordered.

Fineness. 4. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

Soundness. 5. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Time of Setting. 6. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

Tensile Strength. 7. The average tensile strength in pounds per square inch of not less than three standard mortar briquettes (see Section 51) composed of one part cement and three parts standard sand, by weight, shall be equal to or higher than the following:

Age at Test, days.	Storage of Briquettes.	Tensile Strength, lb. per sq. in.
7	1 day in moist air, 6 days in water	200
28	1 day in moist air, 27 days in water	300

8. The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

III. PACKAGES, MARKING AND STORAGE.

Packages and Marking. 9. The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 lb. net. A barrel shall contain 376 lb. net.

Storage. 10. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

IV. INSPECTION.

Inspection.

11. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test, and at least 31 days shall be allowed for the completion of the 28-day test. The cement shall be tested in accordance with the methods hereinafter prescribed. The 28-day test shall be waived only when specifically so ordered.

V. REJECTION.

Rejection.

12. The cement may be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

15. Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

TESTS.

VI. SAMPLING.

Number of Samples.

16. Tests may be made on individual or composite samples as may be ordered. Each test sample should weigh at least 8 lb.

17. (*a*) *Individual Sample.*—If sampled in cars one test sample shall be taken from each 50 bbl. or fraction thereof. If sampled in bins one sample shall be taken from each 100 bbl.

(*b*) *Composite Sample.*—If sampled in cars one sample shall be taken from one sack in each 40 sacks (or 1 bbl. in each 10 bbl.) and combined to form one test sample. If sampled in bins or warehouses one test sample shall represent not more than 200 bbl.

Method of Sampling.

18. Cement may be sampled at the mill by any of the following methods that may be practicable, as ordered:

(*a*) *From the Conveyor Delivering to the Bin.*—At least 8 lb. of cement shall be taken from approximately each 100 bbl. passing over the conveyor.

(*b*) *From Filled Bins by Means of Proper Sampling Tubes.*—Tubes inserted vertically may be used for sampling cement to a maximum depth of 10 ft. Tubes inserted horizontally may be used where the construction of the bin permits. Samples shall be taken from points well distributed over the face of the bin.

(*c*) *From Filled Bins at Points of Discharge.*—Sufficient cement shall be drawn from the discharge openings to obtain samples representative of the cement contained in the bin, as determined by the appearance at the discharge openings of indicators placed on the surface of the cement directly above these openings before drawing of the cement is started.

Treatment of Sample.

19. Samples preferably shall be shipped and stored in air-tight containers. Samples shall be passed through a sieve having 20 meshes per linear inch in order to thoroughly mix the sample, break up lumps and remove foreign materials.

VII. CHEMICAL ANALYSIS.

LOSS ON IGNITION.

Method.

20. One gram of cement shall be heated in a weighed covered platinum crucible, of 20 to 25-cc. capacity, as follows, using either method (*a*) or (*b*) as ordered:

(*a*) The crucible shall be placed in a hole in an asbestos board, clamped horizontally so that about three-fifths of the crucible projects below, and blasted at a full red heat for 15 minutes with an inclined flame; the loss in weight shall be checked by a second blasting for 5 minutes. Care shall be taken to wipe off particles of asbestos that may adhere to the crucible when withdrawn from the hole in the board. Greater neatness and shortening of the time of heating are secured by making a hole to fit the crucible in a circular disk of sheet platinum and placing this disk over a somewhat larger hole in an asbestos board.

(*b*) The crucible shall be placed in a muffle at any tempera-

ture between 900 and 1000° C. for 15 minutes and the loss in weight shall be checked by a second heating for 5 minutes.

21. A permissible variation of 0.25 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 4 per cent. **Permissible Variation.**

INSOLUBLE RESIDUE.

22. To a 1-g. sample of cement shall be added 10 cc. of water and 5 cc. of concentrated hydrochloric acid; the liquid shall be warmed until effervescence ceases. The solution shall be diluted to 50 cc. and digested on a steam bath or hot plate until it is evident that decomposition of the cement is complete. The residue shall be filtered, washed with cold water, and the filter paper and contents digested in about 30 cc. of a 5-per-cent solution of sodium carbonate, the liquid being held at a temperature just short of boiling for 15 minutes. The remaining residue shall be filtered, washed with cold water, then with a few drops of hot hydrochloric acid, 1 : 9, and finally with hot water, and then ignited at a red heat and weighed as the insoluble residue. **Method.**

23. A permissible variation of 0.15 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 0.85 per cent. **Permissible Variation.**

SULFURIC ANHYDRIDE.

24. One gram of the cement shall be dissolved in 5 cc. of concentrated hydrochloric acid diluted with 5 cc. of water, with gentle warming; when solution is complete 40 cc. of water shall be added, the solution filtered, and the residue washed thoroughly with water. The solution shall be diluted to 250 cc., heated to boiling and 10 cc. of a hot 10-per-cent solution of barium chloride shall be added slowly, drop by drop, from a pipette and the boiling continued until the precipitate is well formed. The solution shall be digested on the steam bath until the precipitate has settled. The precipitate shall be filtered, washed, and the paper and contents placed in a weighed platinum crucible and the paper slowly charred and consumed without flaming. The barium sulfate shall then be ignited and weighed. The weight obtained multiplied by 34.3 gives the percentage of sulfuric anhydride. The acid filtrate obtained in **Method.**

the determination of the insoluble residue may be used for the estimation of sulfuric anhydride instead of using a separate sample.

Permissible Variation.

25. A permissible variation of 0.10 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 2.00 per cent.

MAGNESIA.

Method.

26. To 0.5 g. of the cement in an evaporating dish shall be added 10 cc. of water to prevent lumping and then 10 cc. of concentrated hydrochloric acid. The liquid shall be gently heated and agitated until attack is complete. The solution shall then be evaporated to complete dryness on a steam or water bath. To hasten dehydration the residue may be heated to 150 or even 200° C. for one-half to one hour. The residue shall be treated with 10 cc. of concentrated hydrochloric acid diluted with an equal amount of water. The dish shall be covered and the solution digested for ten minutes on a steam bath or water bath. The diluted solution shall be filtered and the separated silica washed thoroughly with water.[1] Five cubic centimeters of concentrated hydrochloric acid and sufficient bromine water to precipitate any manganese which may be present, shall be added to the filtrate (about 250 cc.). This shall be made alkaline with ammonium hydroxide, boiled until there is but a faint odor of ammonia, and the precipitated iron and aluminum hydroxides, after settling, shall be washed with hot water, once by decantation and slightly on the filter. Setting aside the filtrate, the precipitate shall be transferred by a jet of hot water to the precipitating vessel and dissolved in 10 cc. of hot hydrochloric acid. The paper shall be extracted with acid, the solution and washings being added to the main solution. The aluminum and iron shall then be reprecipitated at boiling heat by ammonium hydroxide and bromine water in a volume of about 100 cc., and the second precipitate shall be collected and washed on the filter used in the first instance if this is still intact. To the combined filtrates from the hydroxides of iron and aluminum, reduced in volume if need be, 1 cc. of ammonium hydroxide shall be added, the solution brought

[1] Since this procedure does not involve the determination of silica, a second evaporation is unnecessary.

to boiling, 25 cc. of a saturated solution of boiling ammonium oxalate added, and the boiling continued until the precipitated calcium oxalate has assumed a well-defined granular form. The precipitate after one hour shall be filtered and washed, then with the filter shall be placed wet in a platinum crucible, and the paper burned off over a small flame of a Bunsen burner; after ignition it shall be redissolved in hydrochloric acid and the solution diluted to 100 cc. Ammonia shall be added in slight excess, and the liquid boiled. The lime shall then be reprecipitated by ammonium oxalate, allowed to stand until settled, filtered and washed. The combined filtrates from the calcium precipitates shall be acidified with hydrochloric acid, concentrated on the steam bath to about 150 cc., and made slightly alkaline with ammonium hydroxide, boiled and filtered (to remove a little aluminum and iron and perhaps calcium). When cool, 10 cc. of saturated solution of sodium-ammonium-hydrogen phosphate shall be added with constant stirring. When the crystallin ammonium-magnesium orthophosphate has formed, ammonia shall be added in moderate excess. The solution shall be set aside for several hours in a cool place, filtered and washed with water containing 2.5 per cent of NH_3. The precipitate shall be dissolved in a small quantity of hot hydrochloric acid, the solution diluted to about 100 cc., 1 cc. of a saturated solution of sodium-ammonium-hydrogen phosphate added, and ammonia drop by drop, with constant stirring, until the precipitate is again formed as described and the ammonia is in moderate excess. The precipitate shall then be allowed to stand about two hours, filtered and washed as before. The paper and contents shall be placed in a weighed platinum crucible, the paper slowly charred, and the resulting carbon carefully burned off. The precipitate shall then be ignited to constant weight over a Meker burner, or a blast not strong enough to soften or melt the pyrophosphate. The weight of magnesium pyrophosphate obtained multiplied by 72.5 gives the percentage of magnesia. The precipitate so obtained always contains some calcium and usually small quantities of iron, aluminum, and manganese as phosphates.

Permissible Variation.

27. A permissible variation of 0.4 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 5.00 per cent.

VIII. DETERMINATION OF SPECIFIC GRAVITY.

Apparatus. 28. The determination of specific gravity shall be made with a standardized Le Chatelier apparatus which conforms to the requirements illustrated in Fig. 1. This apparatus is standardized by the United States Bureau of Standards. Kerosene free from water, or benzine not lighter than 62° Baumé, shall be used in making this determination.

Method. 29. The flask shall be filled with either of these liquids to a point on the stem between zero and one cubic centimeter, and 64 g. of cement, of the same temperature as the liquid, shall be slowly introduced, taking care that the cement does not adhere to the inside of the flask above the liquid and to free the cement from air by rolling the flask in an inclined position. After all the cement is introduced, the level of the liquid will rise to some division of the graduated neck; the difference between readings is the volume displaced by 64 g. of the cement.

The specific gravity shall then be obtained from the formula

$$\text{Specific gravity} = \frac{\text{Weight of cement (g.)}}{\text{Displaced volume (cc.)}}$$

30. The flask, during the operation, shall be kept immersed in water, in order to avoid variations in the temperature of the liquid in the flask, which shall not exceed 0°.5 C. The results of repeated tests should agree within 0.01.

31. The determination of specific gravity shall be made on the cement as received; if it falls below 3.10, a second determination shall be made after igniting the sample as described in Section 20.

IX. DETERMINATION OF FINENESS.

Apparatus. 32. Wire cloth for standard sieves for cement shall be woven (not twilled) from brass, bronze, or other suitable wire, and mounted without distortion on frames not less than $1\frac{1}{2}$ in. below the top of the frame. The sieve frames shall be circular, approximately 8 in. in diameter, and may be provided with a pan and cover.

33. A standard No. 200 sieve is one having nominally an 0.0029-in. opening and 200 wires per inch standardized by the

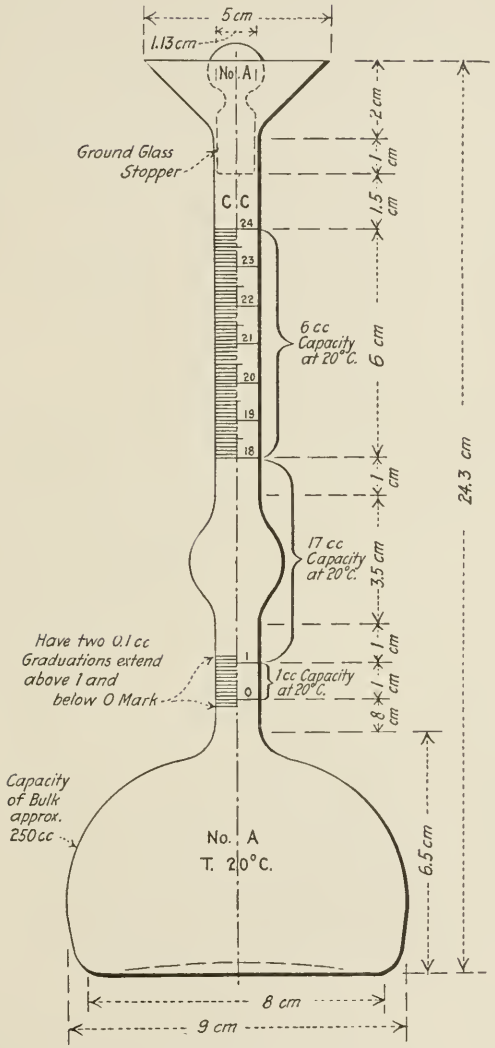


FIG. 1.—Le Chatelier Apparatus.

U. S. Bureau of Standards, and conforming to the following requirements:

The No. 200 sieve should have 200 wires per inch, and the number of wires in any whole inch shall not be outside the limits of 192 to 208. No opening between adjacent parallel wires shall be more than 0.0050 in. in width. The diameter of the wire should be 0.0021 in. and the average diameter shall not be outside the limits 0.0019 to 0.0023 in. The value of the sieve as determined by sieving tests made in conformity with the standard specification for these tests on a standardized cement which gives a residue of 25 to 20 per cent on the No. 200 sieve, or on other similarly graded material, shall not show a variation of more than 1.5 per cent above or below the standards maintained at the Bureau of Standards.

Method. 34. The test shall be made with 50 g. of cement. The sieve shall be thoroughly clean and dry. The cement shall be placed on the No. 200 sieve, with pan and cover attached, if desired, and shall be held in one hand in a slightly inclined position so that the sample will be well distributed over the sieve, at the same time gently striking the side about 150 times per minute against the palm of the other hand on the up stroke. The sieve shall be turned every 25 strokes about one-sixth of a revolution in the same direction. The operation shall continue until not more than 0.05 g. passes through in one minute of continuous sieving. The fineness shall be determined from the weight of the residue on the sieve expressed as a percentage of the weight of the original sample.

35. Mechanical sieving devices may be used, but the cement shall not be rejected if it meets the fineness requirement when tested by the hand method described in Section 34.

Permissible Variation. 36. A permissible variation of 1 will be allowed, and all results in excess of the specified limit but within this permissible variation shall be reported as 22 per cent.

X. MIXING CEMENT PASTES AND MORTARS.

Method. 37. The quantity of dry material to be mixed at one time shall not exceed 1000 g. nor be less than 500 g. The proportions of cement or cement and sand shall be stated by weight in grams of the dry materials; the quantity of water shall be

expressed in cubic centimeters (1 cc. of water = 1 g.). The dry materials shall be weighed, placed upon a non-absorbent surface, thoroughly mixed dry if sand is used, and a crater formed in the center, into which the proper percentage of clean water shall be poured; the material on the outer edge shall be turned into the crater by the aid of a trowel. After an interval of ½ minute for the absorption of the water the operation shall be completed by continuous, vigorous mixing, squeezing and kneading with the hands for at least one minute.[1] During the operation of mixing, the hands should be protected by rubber gloves.

38. The temperature of the room and the mixing water shall be maintained as nearly as practicable at 21° C. (70° F.).

XI. NORMAL CONSISTENCY.

Apparatus.

39. The Vicat apparatus consists of a frame *A* (Fig. 2) bearing a movable rod *B*, weighing 300 g., one end *C* being 1 cm. in diameter for a distance of 6 cm., the other having a removable needle *D*, 1 mm. in diameter, 6 cm. long. The rod is reversible, and can be held in any desired position by a screw *E*, and has midway between the ends a mark *F* which moves under a scale (graduated to millimeters) attached to the frame *A*. The paste is held in a conical, hard-rubber ring *G*, 7 cm. in diameter at the base, 4 cm. high, resting on a glass plate *H* about 10 cm. square.

Method.

40. In making the determination, 500 g. of cement, with a measured quantity of water, shall be kneaded into a paste, as described in Section 37, and quickly formed into a ball with the hands, completing the operation by tossing it six times from one hand to the other, maintained about 6 in. apart; the ball resting in the palm of one hand shall be pressed into the larger end of the rubber ring held in the other hand, completely filling the ring with paste; the excess at the larger end shall then be removed by a single movement of the palm of the hand; the ring shall then be placed on its larger end on a glass plate and

[1] In order to secure uniformity in the results of tests for the time of setting and tensile strength the manner of mixing above described should be carefully followed. At least one minute is necessary to obtain the desired plasticity which is not appreciably affected by continuing the mixing for several minutes. The exact time necessary is dependent upon the personal equation of the operator. The error in mixing should be on the side of over mixing.

the excess paste at the smaller end sliced off at the top of the ring by a single oblique stroke of a trowel held at a slight angle with the top of the ring. During these operations care shall be taken not to compress the paste. The paste confined in the ring, resting on the plate, shall be placed under the rod, the larger end of which shall be brought in contact with the surface

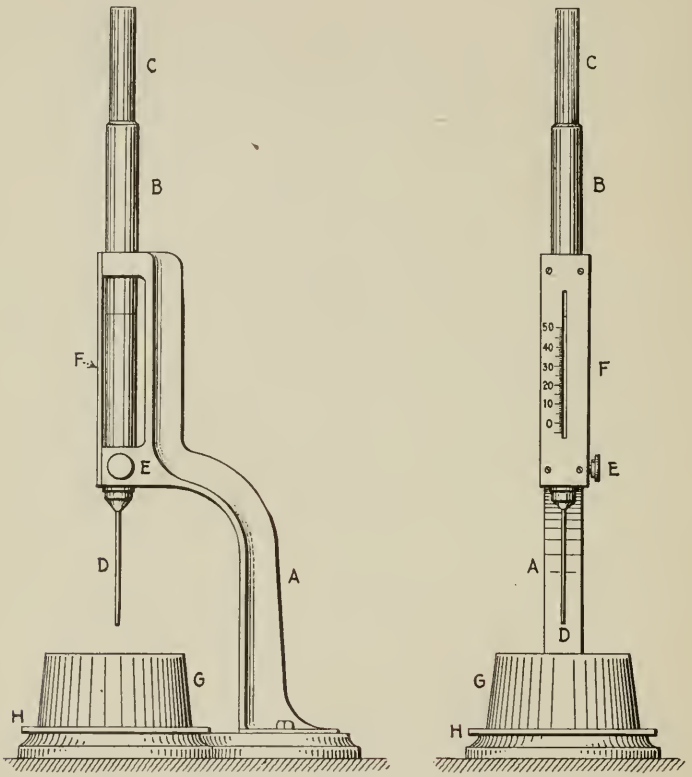


FIG. 2.—Vicat Apparatus.

of the paste; the scale shall be then read, and the rod quickly released. The paste shall be of normal consistency when the rod settles to a point 10 mm. below the original surface in $\frac{1}{2}$ minute after being released. The apparatus shall be free from all vibrations during the test. Trial pastes shall be made with varying percentages of water until the normal consistency

is obtained. The amount of water required shall be expressed in percentage by weight of the dry cement.

41. The consistency of standard mortar shall depend on the amount of water required to produce a paste of normal consistency from the same sample of cement. Having determined the normal consistency of the sample, the consistency of standard mortar made from the same sample shall be as indicated in Table I, the values being in percentage of the combined dry weights of the cement and standard sand.

TABLE I.—PERCENTAGE OF WATER FOR STANDARD MORTARS.

Percentage of Water for Neat Cement Paste of Normal Consistency	Percentage of Water for One Cement, Three Standard Ottawa Sand.	Percentage of Water for Neat Cement Paste of Normal Consistency.	Percentage of Water for One Cement, Three Standard Ottawa Sand.
15	9.0	23	10.3
16	9.2	24	10.5
17	9.3	25	10.7
18	9.5	26	10.8
19	9.7	27	11.0
20	9.8	28	11.2
21	10.0	29	11.3
22	10.2	30	11.5

XII. DETERMINATION OF SOUNDNESS.[1]

Apparatus

42. A steam apparatus, which can be maintained at a temperature between 98 and 100° C., or one similar to that shown in Fig. 3, is recommended. The capacity of this apparatus may be increased by using a rack for holding the pats in a vertical or inclined position.

Method.

43. A pat from cement paste of normal consistency about 3 in. in diameter, ½ in. thick at the center, and tapering to a thin edge, shall be made on clean glass plates about 4 in. square,

[1] Unsoundness is usually manifested by change in volume which causes distortion, cracking, checking or disintegration.

Pats improperly made or exposed to drying may develop what are known as shrinkage cracks within the first 24 hours and are not an indication of unsoundness. These conditions are illustrated in Fig. 4.

The failure of the pats to remain on the glass or the cracking of the glass to which the pats are attached does not necessarily indicate unsoundness.

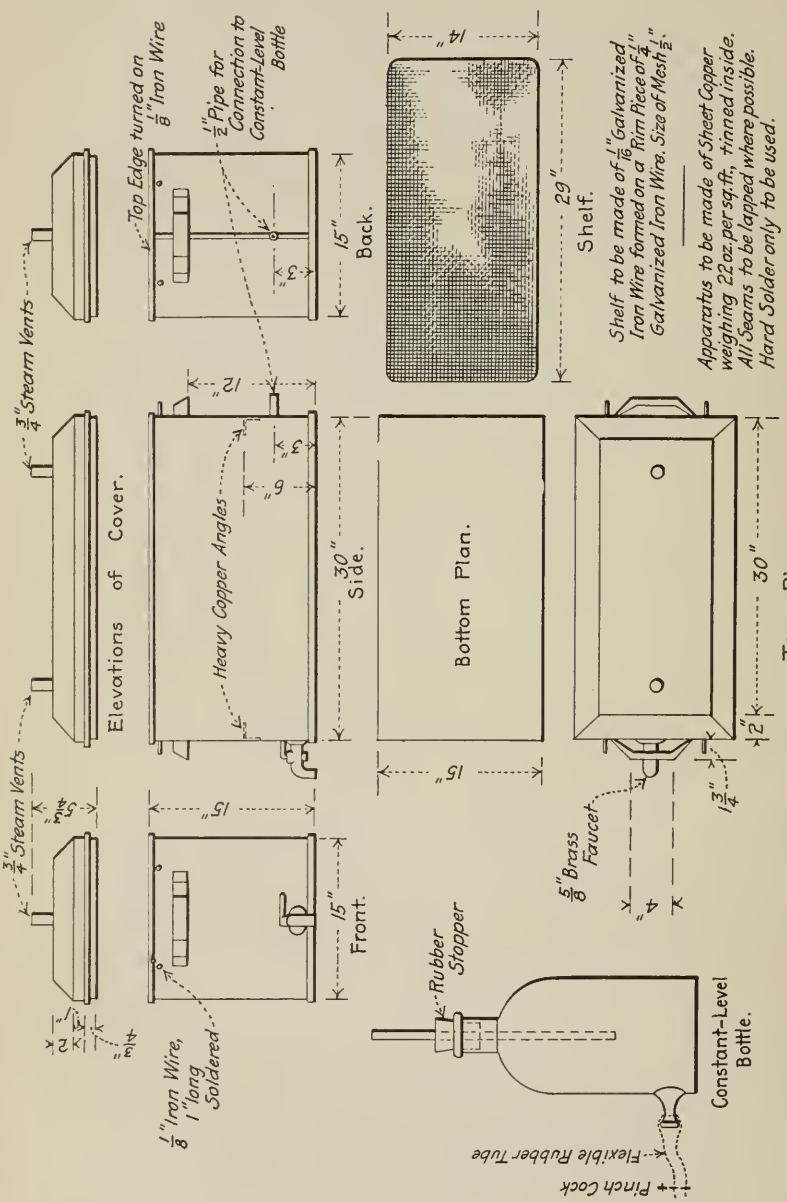

Elevations of Cover.
Heavy Copper Angles
Bottom Plan.
Top Edge turned on 1/8" Iron Wire
1/2" Pipe for Connection to Constant-Level Bottle
3/4" Steam Vents
Back.
Side.
Front.
Shelf.
Shelf to be made of 1/16" Galvanized Iron Wire formed on a Rim Piece of 1/4" Galvanized Iron Wire. Size of Mesh 1/2".
Apparatus to be made of Sheet Copper weighing 22 oz. per sq. ft., tinned inside. All Seams to be lapped where possible. Hard Solder only to be used.
1/8" Iron Wire, 1" long Soldered
Rubber Stopper
5/8" Brass Faucet
Pinch Cock
Flexible Rubber Tube
Constant-Level Bottle.
Top Plan.

FIG. 3.—Apparatus for Making Soundness Test of Cement.

Shrinkage

Shrinkage.

Distortion.

Cracking.

Checking.

Disintegration.

FIG. 4.—Typical Failures in Soundness Test.

and stored in moist air for 24 hours. In molding the pat, the cement paste shall first be flattened on the glass and the pat then formed by drawing the trowel from the outer edge toward the center.

44. The pat shall then be placed in an atmosphere of steam at a temperature between 98 and 100° C. upon a suitable support 1 in. above boiling water for 5 hours.

45. Should the pat leave the plate, distortion may be detected best with a straight edge applied to the surface which was in contact with the plate.

XIII. DETERMINATION OF TIME OF SETTING.

46. The following are alternate methods, either of which may be used as ordered:

Vicat Apparatus.

47. The time of setting shall be determined with the Vicat apparatus described in Section 39. (See Fig. 2.)

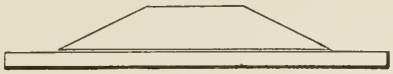
Vicat Method.

48. A paste of normal consistency shall be molded in the hard-rubber ring *G* as described in Section 40, and placed under the rod *B*, the smaller end of which shall then be carefully brought in contact with the surface of the paste, and the rod quickly released. The initial set shall be said to have occurred when the needle ceases to pass a point 5 mm. above the glass plate in $\frac{1}{2}$ minute after being released; and the final set, when the needle does not sink visibly into the paste. The test pieces shall be kept in moist air during the test. This may be accomplished by placing them on a rack over water contained in a pan and covered by a damp cloth, kept from contact with them by means of a wire screen; or they may be stored in a moist closet. Care shall be taken to keep the needle clean, as the collection of cement on the sides of the needle retards the penetration, while cement on the point may increase the penetration. The time of setting is affected not only by the percentage and temperature of the water used and the amount of kneading the paste receives, but by the temperature and humidity of the air, and its determination is therefore only approximate.

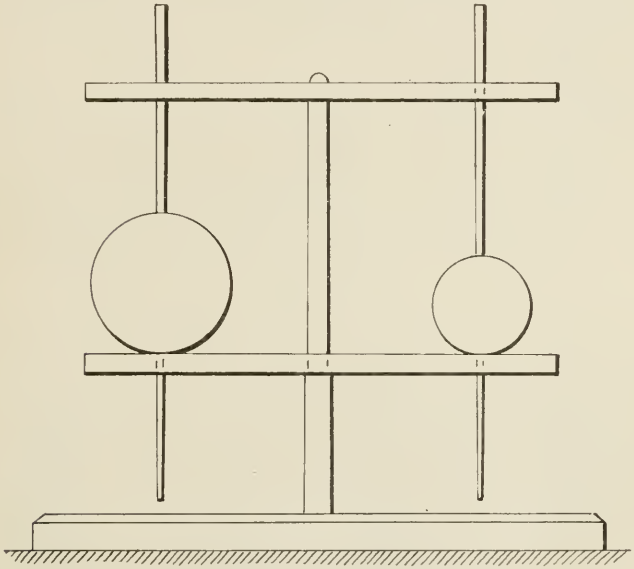
Gillmore Needles.

49. The time of setting shall be determined by the Gillmore needles. The Gillmore needles should preferably be mounted as shown in Fig. 5 (*b*).

50. The time of setting shall be determined as follows: A pat of neat cement paste about 3 in. in diameter and $\frac{1}{2}$ in. in thickness with a flat top (Fig. 5 (*a*)), mixed to a normal consistency, shall be kept in moist air at a temperature maintained as nearly as practicable at 21° C. (70° F.). The cement shall be considered to have acquired its initial set when the pat will bear, **Gillmore Method.**



(*a*) Pat with Top Surface Flattened for Determining Time of Setting by Gillmore Method.



(*b*) Gillmore Needles.

FIG. 5.

without appreciable indentation, the Gillmore needle $\frac{1}{12}$ in. in diameter, loaded to weigh $\frac{1}{4}$ lb. The final set has been acquired when the pat will bear without appreciable indentation, the Gillmore needle $\frac{1}{24}$ in. in diameter, loaded to weigh 1 lb. In making the test, the needles shall be held in a vertical position, and applied lightly to the surface of the pat.

XIV. TENSION TESTS.

Form of Test Piece.

51. The form of test piece shown in Fig. 6 shall be used. The molds shall be made of non-corroding metal and have sufficient material in the sides to prevent spreading during molding. Gang molds when used shall be of the type shown in Fig. 7. Molds shall be wiped with an oily cloth before using.

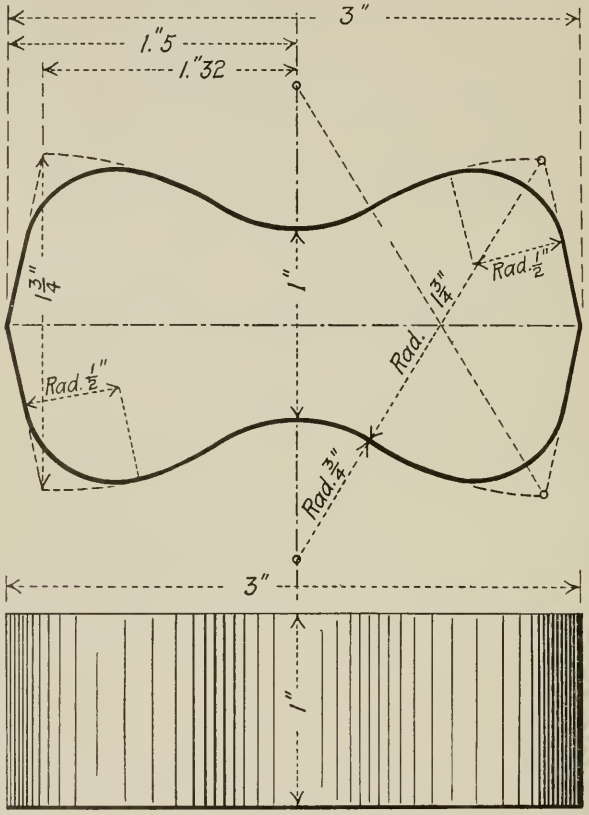


FIG. 6.—Details for Briquette.

Standard Sand.

52. The sand to be used shall be natural sand from Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve. This sand may be obtained from the Ottawa Silica Co., at a cost of two cents per pound, f. o. b. cars, Ottawa, Ill.

53. This sand, having passed the No. 20 sieve, shall be considered standard when not more than 5 g. pass the No. 30 sieve after one minute continuous sieving of a 500-g. sample.

54. The sieves shall conform to the following specifications:

The No. 20 sieve shall have between 19.5 and 20.5 wires per whole inch of the warp wires and between 19 and 21 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0165 in. and the average diameter shall not be outside the limits of 0.0160 and 0.0170 in.

The No. 30 sieve shall have between 29.5 and 30.5 wires per whole inch of the warp wires and between 28.5 and 31.5 wires per whole inch of the shoot wires. The diameter of the wire should be 0.0110 in. and the average diameter shall not be outside the limits 0.0105 to 0.0115 in.

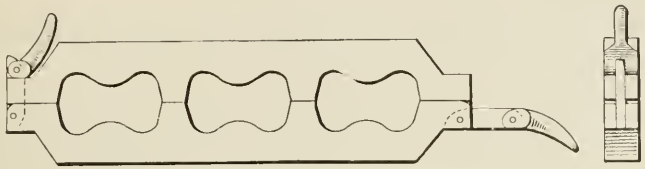


FIG. 7.—Gang Mold.

Molding.

55. Immediately after mixing, the standard mortar shall be placed in the molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold shall then be turned over and the operation of heaping, thumbing and smoothing off repeated.

Testing.

56. Tests shall be made with any standard machine. The briquettes shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquettes shall be free from grains of sand or dirt. The briquettes shall be carefully centered and the load applied continuously at the rate of 600 lb. per minute.

57. Testing machines should be frequently calibrated in order to determine their accuracy.

Faulty Briquettes.

58. Briquettes that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test pieces made from the same sample and broken at the same period, shall not be considered in determining the tensile strength.

XV. STORAGE OF TEST PIECES.

Apparatus.

59. The moist closet may consist of a soapstone, slate or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with non-absorbent shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily.

Methods.

60. Unless otherwise specified all test pieces, immediately after molding, shall be placed in the moist closet for from 20 to 24 hours.

61. The briquettes shall be kept in molds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquettes shall be immersed in clean water in storage tanks of non-corroding material.

62. The air and water shall be maintained as nearly as practicable at a temperature of 21° C. (70° F.).

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS FOR DRAIN TILE.

Serial Designation: C 4 – 16.

The specifications for this material are issued under the fixed designation C 4; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1916.

Classes.

1. (*a*) These specifications cover three classes of drain tile, namely, Farm Drain Tile, Standard Drain Tile, and Extra-Quality Drain Tile.

(*b*) The purposes for which these classes are intended to be suitable are as follows:

Farm Drain Tile, for ordinary private drainage work on farms, for moderate sizes and depths;

Standard Drain Tile, for ordinary district land drainage at moderate depths;

Extra-Quality Drain Tile, for district land drainage, for considerable depths and where an extra quality is desired.

Basis of Purchase.

2. The purchaser shall specify the class or classes of tile to be supplied, whether Farm Drain Tile, Standard Drain Tile, or Extra-Quality Drain Tile. Standard Drain Tile shall be supplied where no other advance selection is stated.

Basis of Acceptance.

3. (*a*) The acceptability of drain tile shall be determined (1) by the results of the chemical and physical tests hereinafter

specified, and (2) by visual inspection, to determine whether the tiles comply with the specifications as to dimensions, shape, and freedom from visible external and internal defects.

(*b*) The acceptance of drain tile as satisfactorily meeting one of these two general requirements shall not be construed as in any way waiving the other.

I. MATERIALS AND MANUFACTURE.

Materials.

4. (*a*) These specifications shall apply to drain tile made of shale, fire clays or surface clays and to drain tile made of concrete.

(*b*) By shale is meant a stratified clay, usually red-burning, more or less indurated by heat or pressure, with well-marked cleavage, laid down prior to the present geological epoch.

(*c*) By fire clay is meant a stratified clay, usually buff-burning, usually less indurated than shales, with poorly marked cleavage, laid down prior to the present geological epoch.

(*d*) By surface clay is meant an unstratified, unconsolidated plastic glacial or alluvial clay, laid down by the glacial ice sheet, or on the flood plains of rivers, during the present geological epoch.

(*e*) By concrete is meant a suitable mixture of Portland cement, mineral aggregates and water, hardened by hydraulic chemical reaction.

(*f*) If the purchaser desires to exclude any of these materials he shall so specify in advance, All materials used shall be first-class of their kind and suitable for the purpose.

Manufacture.

5. The method of manufacture shall be such as to insure excellence of product and uniformity in quality.

II. CHEMICAL TESTS AND REQUIREMENTS.

Chemical Tests and Requirements.

6. The purchaser may prescribe in advance special chemical requirements in cases where drainage waters have marked acid or alkaline character, or are of abnormally high temperature, and may use chemical analysis of the tile to ascertain whether these special requirements are met. Without a special agreement in advance, no drain tile shall be rejected by reason of its composition as determined by ultimate chemical analysis.

The presence in drain tile of visible grains or masses of caustic lime, iron pyrites, or any other minerals which are

known to cause slaking or disintegration of the tile, shall be construed as a valid ground for rejection, unless satisfactory proof be submitted that the tiles are permanent and durable, and that the objectionable minerals are not present in quantity or condition to work damage.

III. PHYSICAL TESTS.

Physical Tests.

7. The physical tests of drain tile shall include (*A*) Strength Tests and (*B*) Absorption Tests; and may include (*C*) Freezing and Thawing Tests, when specified by the purchaser in advance, or when called for by the manufacturer or other seller as provided in Sections 34, 35, 47 and 52.

Selection of Specimens of Tile.

8. The specimens of tile shall all be selected at the factory or at the shipping destination, or at the trench, at the option of the purchaser. The selection shall be made by a competent inspector employed by the purchaser. The inspector shall divide the tile into sub-classes if lack of uniformity in any important particular warrants such division, and shall select enough representative specimens of tile from each subclass for a complete set of standard physical tests.

Number and Cost of Specimens of Tile.

9. A standard physical test shall comprise tests of five individual tiles. Specimens of tile may be selected by the inspector in such number as he judges necessary to determine fairly the quality of all the tile. The manufacturer or other seller shall furnish specimens of tile without separate charge up to 0.5 per cent of the whole number of tile, and the purchaser shall pay for all in excess of that percentage at the same rate as for other tile.

(*A*) *Strength Tests of Drain Tile.*

Specimens of Tile.

10. The specimens of tile shall be unbroken, full-size tile.

Moisture Condition of Specimens of Tile.

11. The walls of the tile shall, at the time of testing, be as thoroughly wet as will result from completely covering with hay, cloth, or similar absorbent material, and keeping the covering wet for not less than 12 hours.

Temperature Condition of Specimens of Tile.

12. No specimen of tile shall be exposed to water or air temperatures lower than 40° F. from the beginning of wetting until tested. Frozen tile shall be completely thawed before the wetting begins.

13. Each specimen of tile shall be weighed on reliable scales just prior to testing, and the weights shall be reported. **Weighing.**

14. Any machine or hand method which will apply the load continuously, or in increments not exceeding 5 per cent of the estimated total breaking load, may be used in making the test. The tile shall not be allowed to stand under load longer than is required for observing and recording the loads. All solid parts of the bearing frames and bearing blocks shall be so rigid that the distribution of the load will not be affected appreciably by the deformation of any part. All bearings and the specimens of tile shall be so accurately centered as to secure a symmetrical distribution of the loading on each side of the center of the tile in every direction. **Application of Load.**

15. The purchaser shall choose (1) sand bearings, (2) hydraulic bearings, or (3) three-point bearings, for use in making strength tests of drain tile. (See Sections 18, 19, and 20). **Choice of Bearings.**

16. The test results shall be calculated and reported, in pounds per linear foot of tile, in terms of the "Ordinary Supporting Strength."[1] **Calculation and Reporting of Test Results.**

The ordinary supporting strength shall be calculated by multiplying the test breaking loads by the following factors: For sand bearings, 1.00; for hydraulic bearings, 1.25; for three-point bearings, 1.50.

The results of the strength tests shall be reported separately for each of the five individual specimens of tile constituting a standard test, together with the average.

17. The modulus of rupture may or may not be calculated and reported, at the option of the purchaser. When reported it shall be calculated by the equations[2] **Modulus of Rupture.**

$$M = 0.20\, r \frac{W}{12} \quad \ldots\ldots (1)$$

$$f = \frac{6M}{t^2} \quad \ldots\ldots (2)$$

[1] The "ordinary supporting strength," when calculated as specified in Section 16, is approximately equal to the actual supporting strength of a tile when laid in a ditch by the "ordinary" method. See note under Table II.

[2] The coefficient of 0.20 in equation (1) approximates the value found by theoretical analysis and also that determined by extended tests.

where M = maximum bending moment in wall in pound-inches per inch of length, r = radius of middle line of tile wall in inches, W = ordinary supporting strength, calculated as prescribed in Section 16, in pounds per linear foot of tile, f = modulus of rupture in pounds per square inch, and t = thickness of tile wall in inches.

Five-eighths of the weight of the tile per linear foot for sand bearings, or three-fourths for hydraulic or three-point bearings, shall be added to W in computing the maximum bending moment M, when such addition exceeds 5 per cent of W. The value of t used shall be the average thickness of the wall at the top of the tile or that at the bottom, selecting the lesser of the two.

Sand Bearings. 18. (See Fig. 1.)—When sand bearings are used, the ends of each specimen of tile shall be accurately marked in quarters of the circumference prior to the test. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the tile measured on the middle line of the wall. The depth of bedding above and below the tile at the thinnest points shall be one-half the radius of the middle line of the wall.

The sand used shall be clean, and shall be such as will pass a No. 4 screen.

The top bearing frame shall not be allowed to come in contact with the tile nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, in such a manner as to permit free motion of the plate in all directions. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weight shall be piled symmetrically about a vertical line through the center of the tile, and that the platform shall not be allowed to touch the top bearing frame.

The frames of the top and bottom bearings shall be made

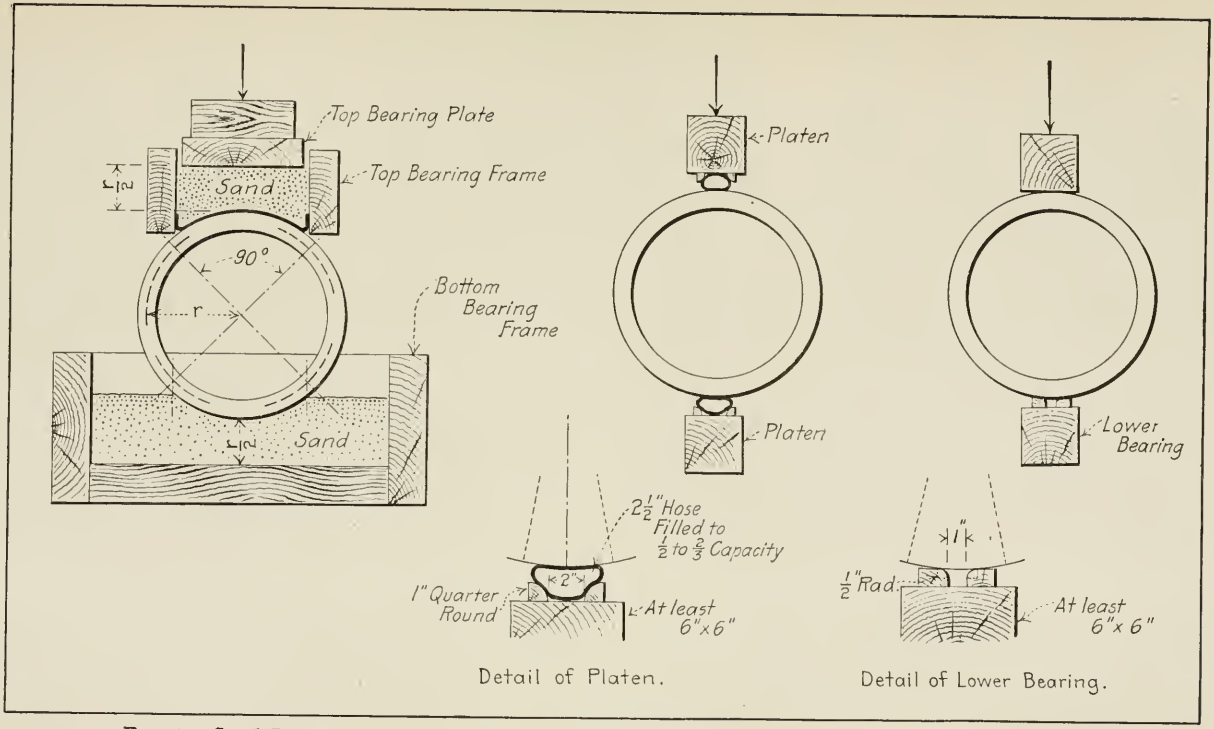


FIG. 1.—Sand Bearings.

FIG. 2.—Hydraulic Bearings.

FIG. 3.—Three-Point Bearings.

of timbers so heavy as to avoid appreciable bending by the side pressure of the sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the tile during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the tile.

Hydraulic Bearings.

19. (See Fig. 2.)—When hydraulic bearings are used, the ends of each specimen of tile shall be accurately marked in halves of the circumference prior to the test.

An hydraulic bearing shall be composed of a wooden platen, to which is attached, as hereinafter described, a section of rubber hose. The hose shall lie against the tile, and the pressure shall be applied to the hose through the platen.

The platen shall be built of strong wood, and shall be not less than 6 by 6 in. in section, and its least length shall be the length of the tile plus 8 in. One-inch quarter rounds, with their convex surfaces facing and 2 in. apart in the clear, shall be firmly attached to the bearing side. The straight portion of this face shall extend at least the length of the tile, and the platen beyond this length may be cut to the arc of a circle.

Between the quarter rounds shall be laid a piece of $2\frac{1}{2}$-in. hose which shall be closed in a water-tight manner at each end by clamps. The hose shall contain a volume of water not less than one-half nor more than two-thirds its capacity, when completely distended. This hose may be attached to the platen at either end in any satisfactory manner which will not induce wrinkling when under test pressure.

The test load shall be applied at the middle of the top bearing, in such a way as to leave the bearing free to move in the vertical plane of the axis of the tile.

It is recommended that stops be screwed to the platen, symmetrical with the point of application of the load, and at a distance apart not greater than the length of the tile plus $\frac{1}{2}$ in. This will help center the load coming upon the tile.

Three-point Bearings.

20. (See Fig. 3.)—When three-point bearings are used, the ends of each specimen of tile shall be accurately marked in halves of the circumference prior to the test.

The lower bearings shall consist of two wooden strips with

vertical sides, each strip having its interior top corner rounded to a radius of approximately ½ in. They shall be straight, and shall be securely fastened to a rigid block with their interior vertical sides 1 in. apart.

The upper bearing shall be a wooden block, straight and true from end to end.

The test load shall be applied through the upper bearing block in such a way as to leave the bearing free to move in a vertical plane passing midway between the lower bearings.

In testing a tile which is "out of straight," the lines of the bearings chosen shall be from those which appear to give most favorable conditions for fair bearings.

(*B*) *Absorption Tests of Drain Tile.*

Test Specimens.

21. Not less than three separate test specimens from each of five separate tiles shall be taken as a "standard sample" for the absorption test. Of the three specimens from each tile, one shall be taken from one end, another from the opposite end, and the third shall be taken from the middle portion of the tile. Each specimen shall be of from 12 to 20 sq. in. in area, measured upon the exterior or convex side, and shall be as nearly square as the nature of the material will readily permit. The specimens shall be obtained by breaking the tile, and shall be apparently sound, solid pieces of the wall of the tile, and shall not show cracks or fissures or shattered edges due to the shock of breaking or cutting. The specimens may be obtained from the broken pieces of the tiles used in the strength test, if the restrictions as to the size and location of the specimens can be duly obserbed. The specimens shall be so marked as to permit the identity of each one to be ascertained at any stage of the test.

Drying Test Specimens.

22. Preparatory to the absorption test, all specimens shall be first weighed and then dried in a drier or oven, at a temperature of not less than 110° C. (230° F.) for not less than three hours. After removal from the drier, the specimens shall be allowed to cool to a temperature of 20 to 25° C. (68 to 77° F.) and reweighed. If the specimens were apparently dry when taken, and the second weight closely checks the first, the specimens shall be considered dry. If the specimens were known to

be wet when taken, they shall be placed in the drier for a further drying treatment of two hours, and reweighed. If the third weight checks the second, the specimens shall be considered dry. In case of any doubt, the specimens must be redried for two-hour periods until check weights are obtained.

Weighing and Reweighing.

23. The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same order of accuracy must be obtained.

In reweighing after immersion, the specimens shall be removed from the water, not allowed to drain for more than one minute, the superficial water removed by towel or blotting paper, and the specimens at once put upon the balance.

Immersion of Test Specimens.

24. Specimens after weighing shall be placed in a suitable woven-wire receptacle, packed tightly enough to prevent jostling, covered with distilled water or rainwater, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of 10 to 15° C. (50 to 59° F.).

Calculation and Reporting of Results.

25. The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each individual specimen, together with the mean of the fifteen or more specimens comprising the standard sample, the maximum and the minimum single observations entering into the mean, and the variation between the maximum and the minimum of the three specimens of each tile represented in the the standard sample.

(C) *Freezing and Thawing Tests of Drain Tile.*

Test Specimens.

26. The test specimens employed in making the absorption test shall preferably be used for the freezing and thawing test. In the event that the same specimens are not available, another set selected as specified in Section 21 shall be taken.

Drying Test Specimens.

27. In the event that new specimens for the freezing and thawing test must be prepared, they shall be dried as specified in Section 22.

Weighing and Reweighing.

28. The same scales and weights as are specified in Section 23 for the absorption test or others of equivalent sensitiveness and accuracy shall be employed for the weighings required in

the freezing and thawing test. The same procedure in weighings and reweighing as specified in Section 23 shall be used.

Immersion of Test Specimens.

29. In the event that new specimens for the freezing and thawing test must be prepared, they shall be immersed and boiled and cooled in water as specified in Section 24.

Freezing and Thawing.

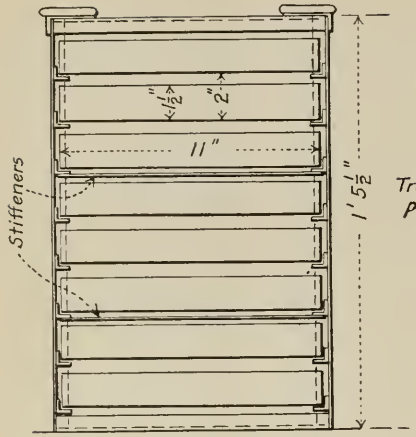
30. When the specimens (either from the absorption test or from a specially prepared series) have been weighed after saturation with water, they shall be returned to the water, and kept immersed till the freezing test is begun. For freezing, they shall be placed with their concave faces upward in watertight metal trays, suitably mounted in a rigid metal crate,[1] and immersed in ice water until the specimens have attained substantially the temperature of the water, after which the water shall be drawn down to a depth of $\frac{1}{2}$ in. in each tray. The crate shall then be lifted as a whole, without disturbing the specimens, and placed in the freezing apparatus.

Freezing shall be performed in a quiet atmosphere, free from perceptible natural or artificial currents. If artificial freezing apparatus is employed,[2] the apparatus shall have sufficient heat-absorbent capacity to enable the temperature of the freezing chamber to be brought to $-10°$ C. ($+14°$ F.) or below, within thirty minutes after the introduction of the specimens. The temperature in the freezing apparatus shall not fall lower than $-20°$ C. ($-4°$ F.). The freezing shall be continued until the water in the trays is frozen solid. Exposure to freezing conditions in excess of this requirement shall be considered as without significance.

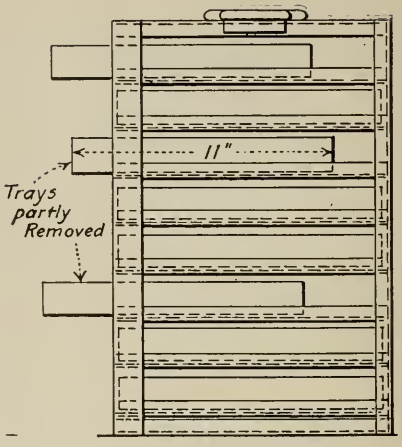
At the conclusion of freezing under the specified conditions, the crate of specimens shall be withdrawn and at once immersed in water at a temperature of 85 to 100° C. (185 to 212° F.) in a special receptacle of proper size. Heating shall be continued so that the water will regain the required temperature as soon as practicable after the specimens are immersed. A temperature of 85 to 100° C. (185 to 212° F.) shall then be maintained for not less than 15 minutes. At the conclusion of

[1] Fig. 4 shows a crate and trays suitable for use in the box for artificial freezing illustrated in Plate I.

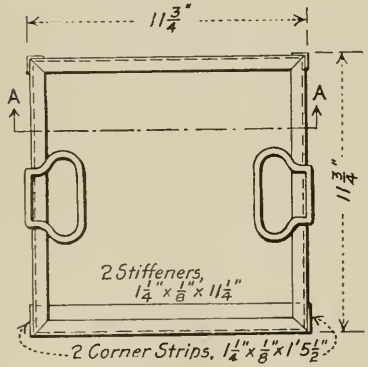
[2] Artificial freezing will generally be necessary. It may be conducted in a commercial zero (F.) refrigerating room, or in an artificial freezing box similar to the one shown in Plate I, in which zero (F.) temperatures can readily be produced by the use of salt and ice



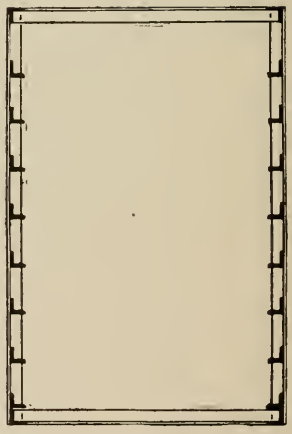
Front Elevation.



Side Elevation.



Top View,
Trays Removed.



Section A-A,
Trays Removed.

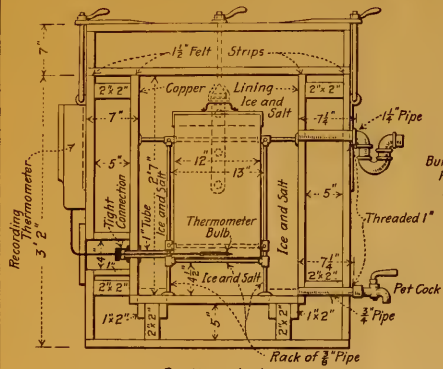
Notes:

Rack Constructed of ⅝" x ⅝" x ⅛" Galvanized Angles, except as Noted.

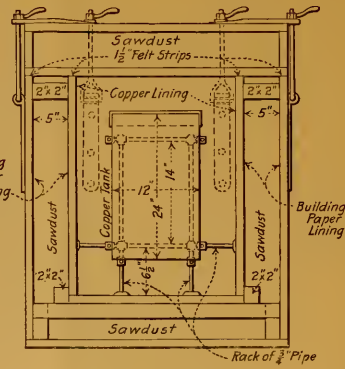
All Connections Riveted or Soldered.

Trays, 11" x 11" x 1½" outside, Made of No. 17 Galvanized Steel.

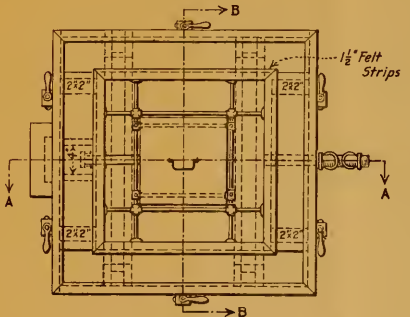
FIG. 4.—Suggested Plans for Freezing Crate and Trays.



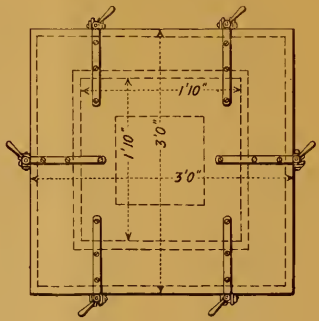
Section A-A.



Section B-B



Plan View,
Top Removed.



Plan View, Top in Place

Note: Box to be Constructed of Seasoned White Pine, free from Defects, or other Suitable Timber, 1"x 6", unless otherwise Specified.

SUGGESTED PLANS
FOR
FREEZING BOX
USING SALT AND ICE TO FREEZE

the thawing treatment, the crate of specimens shall be cooled down rapidly in water to 10 to 15° C. (50 to 59° F.) and then inspected. The condition of each sample after each thawing shall be noted in the records.

Method of Determining Failure in Freezing and Thawing Tests.

31. Failure under the freezing and thawing treatment shall be considered to be reached when:

(*a*) The specimens show superficial disintegration or spalling with loss of weight of more than 5 per cent of the initial dry weight; or,

(*b*) The specimens are badly cracked in other than lamination planes; or,

(*c*) The specimens show evident serious loss of structural strength.

IV. PHYSICAL TEST REQUIREMENTS.

Physical Test Requirements.

32. The physical test requirements for the different classes of drain tile shall be as given in Table I.

Absorption Requirements for Drain Tile made of Mixed Clays.

33. Drain tile made of mixtures of surface clays with other clays shall conform to the absorption requirements for surface-clay tile in Table I, when the proportion of surface clay is 75 per cent or more, and to the requirements for shale and fire-clay tile for all other proportions.

Appeal from Absorption Test to Freezing and Thawing Test.

34. In the event that a standard sample (Section 21) of tile fails to meet the requirements of the absorption test, the manufacturer or other seller may demand recourse to the freezing and thawing test, to be made at his expense. In such recourse, the number of tiles tested shall be four times the number represented by the standard sample (Section 21). If the material passes the freezing and thawing test satisfactorily, it shall not be rejected on account of its failure to meet the absorption requirements specified in Table I, but the average percentage of absorption of the specimens used in the freezing and thawing test shall be adopted as the maximum allowable mean absorption for the contract in question.

Limits of Fluctuation of Individual Test Specimens in Physical Tests; Culling and Retesting when Limits Exceeded.

35. In the strength tests, individual tiles of a standard test whose mean strength is satisfactory may fall 25 per cent below the requirement for the average without causing rejection. In the absorption test, the absorption of individual tiles of a standard sample (Section 21), which gives a satisfactory mean

absorption percentage, may exceed the average by 25 per cent without causing rejection. In the freezing and thawing test, at least 95 per cent of all the tiles tested shall meet the requirement.

In the event of the failure of a standard sample (Sections 9, 21 and 26) to meet the above requirements, the manufacturer

TABLE I.—PHYSICAL-TEST REQUIREMENTS FOR DIFFERENT CLASSES OF DRAIN TILE.

Internal Diameter of Tile, in.	Farm Drain Tile.				Standard Drain Tile.				Extra-Quality Drain Tile.			
	Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent.			Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent.			Minimum Average Ordinary Supporting Strength, lb. per linear ft.	Maximum Average Absorption by Standard Boiling Test, per cent.		
		Shale and Fire-Clay Tile.	Surface-Clay Tile.	Concrete Tile.		Shale and Fire-Clay Tile.	Surface-Clay Tile.	Concrete Tile.		Shale and Fire-Clay Tile.	Surface-Clay Tile.	Concrete Tile.
4	800	11	14	12	1200	9	13	11	1600	7	11	10
6	800	11	14	12	1200	9	13	11	1600	7	11	10
8	800	11	14	12	1200	9	13	11	1600	7	11	10
10	800	11	14	12	1200	9	13	11	1600	7	11	10
12	800	11	14	12	1200	9	13	11	1600	7	11	10
14	900	11	14	12	1200	9	13	11	1600	7	11	10
16	1000	11	14	12	1300	9	13	11	1600	7	11	10
18					1400	9	13	11	1800	7	11	10
20					1500	9	13	11	2000	7	11	10
22					1600	9	13	11	2200	7	11	10
24					1700	9	13	11	2400	7	11	10
26					1800	9	13	11	2600	7	11	10
28					1900	9	13	11	2800	7	11	10
30	(Not Permitted)	(Not Permitted)	(Not Permitted)	(Not Permitted)	2000	9	13	11	3000	7	11	10
32					2100	9	13	11	3200	7	11	10
34					2200	9	13	11	3400	7	11	10
36					2300	9	13	11	3600	7	11	10
38					2400	9	13	11	3800	7	11	10
40					2500	9	13	11	4000	7	11	10
42					2600	9	13	11	4200	7	11	10

NOTE.—When the freezing and thawing test is specified or demanded, as provided in Section 7, the number of freezings and thawings to be endured shall be as follows: For farm drain tile, 8; for standard drain tile, 12; for extra-quality drain tile, 16.

or other seller may thoroughly cull the material and submit a portion of retest at his own expense, and for such retest the number of tiles per sample shall be 10 for the strength and absorption tests and 20 for the freezing and thawing test. In the event of the failure of the material after culling to pass the requirements, it shall be rejected without further test.

TABLE II.—STANDARD ORDINARY SUPPORTING STRENGTHS OF DRAIN TILE FOR ORDINARY SAND AND FOR THOROUGHLY WET CLAY DITCH FILLING MATERIALS.

STRENGTHS IN POUNDS PER LINEAR FOOT.

Height of Fill above Top of Tile, ft.	Breadth of Ditch at Top of Tile.																			
	1 ft.				2 ft.				3 ft.				4 ft.				5 ft.			
	Method of Laying Pipe.				Method of Laying Pipe.				Method of Laying Pipe.				Method of Laying Pipe.				Method of Laying Pipe.			
	Ordinary.		First Class.		Ordinary.		First Class.		Ordinary.		First Class.		Ordinary.		First Class.		Ordinary.		First Class.	
	Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.		Ditch Filling Material.	
	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.	Sand.	Clay.
2	265	280	220	235	615	635	510	530	970	990	810	830	1 330	1 350	1 110	1 130	1 690	1 710	1 410	1 430
4	400	450	335	375	1 050	1 120	880	935	1 750	1 820	1 460	1 520	2 450	2 540	2 040	2 110	3 160	3 250	2 640	2 710
6	470	545	390	455	1 370	1 500	1 140	1 250	2 370	2 530	1 980	2 110	3 410	3 580	2 840	2 980	4 460	4 640	3 720	3 870
8	505	605	420	505	1 600	1 790	1 330	1 490	2 870	3 110	2 390	2 590	4 220	4 490	3 510	3 740	5 590	5 890	4 660	4 910
10	525	640	440	535	1 760	2 010	1 470	1 680	3 270	3 610	2 730	3 010	4 900	5 290	4 080	4 410	6 590	7 020	5 490	5 850
12	535	660	445	550	1 880	2 190	1 570	1 820	3 600	4 030	3 000	3 355	5 480	6 000	4 570	5 000	7 460	8 030	6 220	6 690
14	540	675	450	560	1 960	2 320	1 640	1 930	3 850	4 380	3 210	3 650	5 980	6 620	4 980	5 520	8 230	8 950	6 850	7 460
16	545	680	455	565	2 030	2 420	1 690	2 020	4 060	4 670	3 390	3 890	6 400	7 160	5 330	5 970	8 890	9 770	7 410	8 150
18	545	685	455	570	2 070	2 500	1 720	2 090	4 230	4 920	3 530	4 100	6 750	7 630	5 630	6 360	9 480	10 520	7 900	8 770
20	545	690	455	575	2 100	2 560	1 750	2 140	4 370	5 130	3 640	4 280	7 050	8 060	5 880	6 720	9 990	11 200	8 330	9 330
22	545	690	455	575	2 120	2 610	1 770	2 180	4 470	5 310	3 730	4 420	7 310	8 430	6 090	7 020	10 400	11 800	8 700	9 830
24	545	690	455	575	2 140	2 650	1 780	2 210	4 560	5 450	3 800	4 540	7 520	8 750	6 270	7 290	10 800	12 300	9 030	10 300
26	545	690	455	575	2 150	2 670	1 790	2 230	4 630	5 580	3 850	4 640	7 700	9 030	6 420	7 530	11 200	12 800	9 320	10 700
28	545	690	455	575	2 160	2 700	1 800	2 250	4 680	5 680	3 900	4 740	7 860	9 280	6 550	7 740	11 500	13 300	9 570	11 100
30	545	690	455	575	2 170	2 710	1 810	2 260	4 730	5 770	3 940	4 810	7 990	9 500	6 660	7 920	11 800	13 700	9 800	11 400
Very great...	545	690	455	575	2 180	2 770	1 820	2 310	4 910	6 230	4 090	5 190	8 730	11 100	7 270	9 230	13 600	17 300	11 400	14 400

NOTE.—Ordinary Pipe Laying is pipe laying in accordance with customary good practice in tile-drain construction, whereby the underside of the pipe is well bedded on soil for 60 to 90 deg. of the circumference.

First-Class Pipe Laying is pipe laying in accordance with the best customary practice in pipe-sewer construction, whereby the entire underside of the pipe is very thoroughly bedded on soil and the entire pipe is surrounded by well-compacted soil, under the direction of an inspector constantly present on the work.

When pipe is laid in a Concrete or Other Permanent Masonry Cradle, strong enough to carry the entire load to the sub-base without breaking and large enough to prevent material settlement, the standard strengths for all dimensions of ditches and all filling materials shall be those specified for Standard Drain Tile in Table I.

Strength Test Requirements when Manufacturer is held Responsible for Cracking in Ditches.

36. The manufacturer or other seller shall not be held responsible for cracking of drain tile in ditches unless by special agreement in advance, and in any event his obligation shall be held to be discharged by the delivery of drain tile having the minimum ordinary supporting strengths specified in Table II; and, if it is not otherwise specified in advance by the purchaser, tile shall be supplied of the strengths specified for clay ditch filling, for "ordinary" pipe laying and for widths of ditch at the level of the top of the tile equal to 0.5 ft. greater than the outside diameters of the tile. The purchaser shall furnish to the manufacturer or other seller complete information, in advance of receiving bids, as to the number of linear feet of drain tile of each diameter required for each different depth of ditch, measured to the nearest foot from the surface of the ground to the top of the tile.

V. VISUAL INSPECTION.

Visual Inspection and its Purposes.

37. All drain tile shall be given a thorough visual inspection at the trench by a competent inspector employed by the purchaser. The purposes of the visual inspection shall be: (1) to cull and reject imperfect individual tiles; and (2) to determine whether the tiles, independently of meeting the chemical and the physical test requirements, comply with the specifications of general properties, especially as stated hereinafter.

Shape.

38. All drain tile shall be of approximately circular cross-section, except when otherwise specified in advance. They shall be approximately straight, except in the case of special connections. The ends shall be so regular and smooth as readily to admit of making close joints by turning and pressing together adjoining tile.

Nominal Sizes.

39. The sizes of drain tile shall be designated by their interior diameters.

Minimum Lengths.

40. Drain tile smaller than 12 in. in diameter shall have a minimum length of 12 in. Tile of from 12 to 30 in. in diameter, inclusive, shall have lengths not less than the diameters. Tile larger than 30 in. in diameter shall have a minimum length of 30 in.

Structure.

41. Drain tile shall be substantially uniform in structure throughout, and the inspector shall investigate this property by examining fractured surfaces.

42. Drain tile shall give a clear ring when stood on end and while dry tapped with a light hammer. **Ring.**

43. The inspector may use the color of drain tile as a general guide in sorting and inspecting, but he shall first so familiarize himself with the raw materials and the processes used in the manufacture of the particular tile in question as to be competent to interpret the true meaning of variations in their color. **Color.**

44. Drain tile shall be reasonably smooth on the inside. **Inside Smoothness.**

45. Drain tile shall be free from cracks and checks extending into the body of the tile in such a manner as to decrease the strength appreciably. Tile shall not be chipped or broken **Cracks, Checks, Chips and Broken Pieces.**

TABLE III.—DISTINCTIVE GENERAL PHYSICAL PROPERTIES OF DIFFERENT CLASSES OF DRAIN TILE.

Physical Properties Specified.	Farm Drain Tile.	Standard Drain Tile.	Extra-Quality Drain Tile.
Allowable variation of average diameter below specified diameter, per cent	5	3	3
Allowable variation between maximum and minimum diameters of same tile, or average diameters of adjoining tile, percentage of thickness of wall	85	75	65
Allowable variation from straightness, percentage of length	5	3	3
Allowable thickness of exterior blisters, lumps and flakes which do not weaken tile and are few in number, percentage of thickness of wall	25	20	15
Allowable diameters of above blisters, lumps and flakes, percentage of internal diameter	20	15	10
General Inspection	Careful.	Rigid.	Very rigid.

in such a manner as to decrease their strength materially or to admit earth into the drain.

46. All drain tile shall be sufficiently "vitrified" or "hard-burned" to afford the degree of supporting strength, percentage of absorption, and resistance to freezing and thawing specified in the physical test requirements prescribed in Table I. **Use of the Terms Vitrified and Hard-Burned.**

47. The manufacturer or other seller may appeal from decisions of the inspector on questions of strength or structure when such decisions are based on visual inspection alone, in which case the point at issue shall be determined by standard physical tests, the cost of which shall be paid by the appellant, if the inspector was right, or by the purchaser if his inspector was in error. **Appeal from results of Visual Inspection.**

Additional Distinctive Physical Characteristics.

48. Drain tile of the different classes shall, in addition to all requirements heretofore specified, have the distinctive physical characteristic prescribed in Table III.

VI. TESTING, INSPECTION AND REJECTION.

Making and Reporting Tests.

49. All tests shall be made by experts employed by the purchaser. Full reports of all tests shall be furnished the manufacturer or other seller on his request. Tests shall be made and reported promptly.

Expense of Making Tests.

50. The purchaser shall pay the expense of making all tests except as otherwise specified in Sections 9, 34, 35, 47 and 52.

Number of Tests.

51. The number of standard tests to be made shall be determined by the purchaser.

General Tests and Inspection at Factory.

52. In all contracts for ten or more carloads of tile, preliminary general tests and inspection shall be made at the factory by the purchaser upon demand of the manufacturer or other seller. The expense of such tests and inspection shall be paid by the manufacturer or other seller.

Inspector.

53. The inspector shall be employed by the purchaser.

Inspection.

54. The manufacturer or other seller of the drain tile shall afford the inspector all reasonable facilities for his work, both as to the selection of specimens for tests, and as to visual inspection. Inspection shall be completed promptly.

Rejection.

55. The inspector shall plainly mark all drain tile which he rejects, and such rejected tile shall be removed promptly by the manufacturer or other seller. Upon request of the purchaser, the manufacturer or other seller shall give full account of the removal of rejected tile.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

PAVING BRICK.

Serial Designation: C 7–15.

The specifications for this material are issued under the fixed designation C 7; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1915.

The quality and acceptability of paving brick, in the absence of other special tests mutually agreed upon in advance by the seller on the one side and the buyer on the other side shall be determined by the following procedure:

I. *The Rattler Test*, for the purpose of determining whether the material as a whole possesses to a sufficient degree strength, toughness and hardness.

II. *Visual Inspection*, for the purpose of determining whether the physical properties of the material as to dimensions, accuracy and uniformity of shape and color, are in general satisfactory, and for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick.

The acceptance of paving brick as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

I. THE RATTLER TEST.

THE SELECTION OF SAMPLES FOR TEST.

1. *Place of Sampling.*—In general, where a shipment of bricks involving a quantity of less than 100,000 is under consideration, the sampling may be done either at the brick factory prior to shipment, or on cars at their destination or on the street, when delivered ready for use. When the quantity under consideration exceeds 100,000 the sampling shall be done at the factory prior to shipment. Bricks accepted as the result of test prior to shipment, shall not be liable to subsequent rejection as a whole, but are subject to such culling as is provided for under Part II, Visual Inspection.

2. *Method of Selecting Samples.*—In general, the buyer shall select his own samples from the material which the seller proposes to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include bricks which would be rejected by visual inspection as provided in Part II, except that where controversy arises, whole tests may be selected to determine the admissibility of certain types or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller and samples selected by each party fail to show reasonable concurrence, then both parties shall unite in the selection of a disinterested person to select the samples, and both parties shall be bound by the results of samples thus selected.

3. *Number of Samples per Lot.*—In general, one sample of ten bricks shall be tested for every 10,000 bricks contained in the lot under consideration; but where the total quantity exceeds 100,000, the number of samples tested may be fewer than one per 10,000, provided that they shall be distributed as uniformly as practicable over the entire lot.

4. *Shipment of Samples.*—Samples which must be transported long distances by freight or express shall be carefully put up in packages holding not more than twelve bricks each. When more than six bricks are shipped in one package, it shall be so arranged as to carry two parallel rows of bricks side by

side, and these rows shall be separated by a partition. In event of some of the bricks being cracked or broken in transit, the sample shall be disqualified if there are not remaining ten sound undamaged bricks.

5. *Storage and Care of Samples.*—Samples shall be carefully handled to avoid breakage or injury. They shall be kept in the dry so far as practicable. If wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours in a temperature of 100° F. before testing.

THE CONSTRUCTION OF THE RATTLER.

6. *General Design.*—The machine shall be of good mechanical construction, self-contained, and shall conform to the following details of material and dimensions, and shall consist of barrel, frame, and driving mechanism as herein described. Accompanying these specifications is a complete drawing of a rattler which will meet the requirements, and to which reference should be made (Plate II).

7. *The Barrel.*—The barrel of the machine shall be made up of the heads, headliners, staves and stave-liners.

The heads may be cast in one piece with the trunnions, which shall be $2\frac{1}{2}$ in. in diameter, and shall have a bearing 6 in. in length, or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{16}$-in. shafts, and shall be keyseated for two keys, each $\frac{1}{2}$ by $\frac{3}{8}$ in. and spaced 90 deg. apart. The shaft shall be a snug fit and when keyed shall be entirely free from lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ in. in the head for the driving end of the rattler, and $11\frac{3}{8}$ in. for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ in.

The heads shall be not less than $\frac{3}{4}$ in. thick, nor more than $\frac{7}{8}$ in. thick. In outline, each head shall be a regular 14-sided polygon inscribed in a circle $28\frac{3}{8}$ in. in diameter. Each head shall be provided with flanges not less than $\frac{3}{4}$ in. thick and extending outward $2\frac{1}{2}$ in. from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head shall be smooth and give a true and uniform bearing

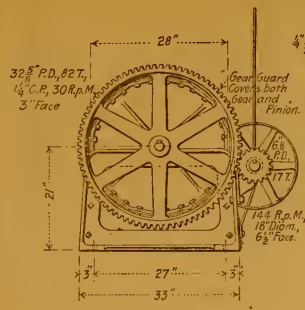
for the staves. To secure the desired true and uniform bearing the surfaces of the flanges of the head shall be either ground or machined. The flanges shall be slotted on the outer edge, so as to provide for two $\frac{3}{4}$-in. bolts at each end of each stave, said slots to be $\frac{13}{16}$ in. wide and $2\frac{3}{4}$ in., center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace $\frac{3}{8}$ in. thick, extending down the outward side of the head not less than 2 in.

There shall be for each head a cast-iron headliner 1 in. in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{1}{8}$ in. in diameter. This headliner shall be fastened to the head by seven $\frac{5}{8}$-in. cap-screws, through the head from the outside. Whenever these headliners become worn down $\frac{1}{2}$ in. below their initial surface level at any point of their surface, they shall be replaced with new ones. The metal of these headliners shall be hard machinery iron and should contain not less than one per cent of combined carbon.

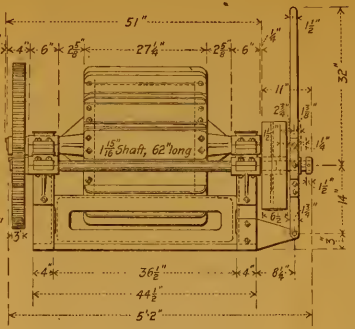
The staves shall be made of 6-in. medium-steel structural channels, $27\frac{1}{4}$ in. long and weighing 15.5 lb. per lineal foot. The staves shall have two holes $\frac{13}{16}$ in. in diameter, drilled in each end, the center line of the holes being 1 in. from the end and $1\frac{3}{8}$ in. either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but shall not exceed $\frac{5}{16}$ in.

The interior or flat side of each stave shall be protected by a liner $\frac{3}{8}$ in. thick by $5\frac{1}{2}$ in. wide by $19\frac{3}{4}$ in. long. The liner shall consist of medium-steel plate, and shall be riveted to the channel by three $\frac{1}{2}$-in. rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 in. from the center each way. The rivet holes shall be countersunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once re-riveted.

Any test at the expiration of which a stave-liner is found detached from the stave or seriously out of position shall be rejected. When a new rattler, in which a complete set of new staves is furnished, is first put into operation, it shall be charged



End Elevation.

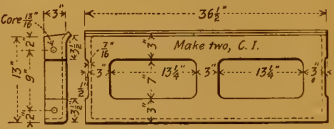


Side Elevation.

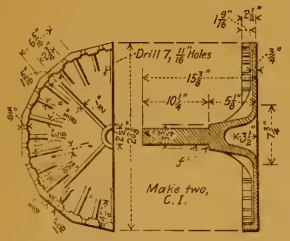
Head Liner.

Stave.

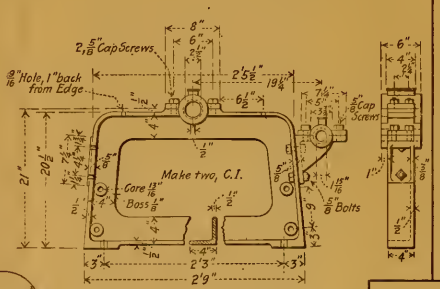
Clutch Lever.



Side Frame.



Trunnion.



End Frame.

Spherical Shot.

STANDARD RATTLER FOR TESTING PAVING BRICK

PROPOSED BY

THE NATIONAL PAVING BRICK MANUFACTURERS' ASSOCIATION

December 1, 1910

with 400 lb. of shot of the same sizes, and in the same proportions as provided in Section 9, and shall then be run for 18,000 revolutions at the usual prescribed rate of speed. The shot shall then be removed and a standard shot charge inserted, after which the rattler may be charged with brick for a test.

No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time in such a way that of each pair, one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive but not contiguous; for example, 1 and 8, 3 and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative condition of repair. The changes in the staves should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of new lined staves was placed in position.

The staves when bolted to the heads shall form a barrel 20 in. long, inside measurement, between head liners. The liners of the staves shall be so placed as to drop between the head-liners. The staves shall be bolted tightly to the heads by four $\frac{3}{4}$-in. bolts, and each bolt shall be provided with a lock nut, and shall be inspected at not less frequent intervals than every fifth test and all nuts kept tight. A record shall be made after each inspection showing in what condition the bolts were found

8. *The Frame and Driving Mechanism.*—The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates, and shall be fastened thereto by bolts at not less than four points.

It shall be driven by gearing whose ratio of driver to driven is not less than one to four. The counter shaft upon which the driving pinion is mounted shall not be less than $1\frac{15}{16}$ in. in diameter, with bearing not less than 6 in. in length. If a belt drive is used the pulley shall not be less than 18 in. in diameter and $6\frac{1}{2}$ in. in face. A belt at least 6 in. in width properly adjusted, to avoid unnecessary slipping, should be used.

9. *The Abrasive Charge.*—The abrasive charge shall consist of cast-iron spheres of two sizes. When new, the larger spheres shall be 3.75 in. in diameter and shall weigh approximately 7.5 lb. (3.40 kg.) each. Ten spheres of this size shall be used.

These shall be weighed separately after each ten tests, and if the weight of any large sphere falls to 7 lb. (3.175 kg.) it shall be discarded and a new one substituted; provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that so far as possible the large spheres shall compose a graduated series in various stages of wear.

When new, the smaller spheres shall be 1.875 in. in diameter and shall weigh approximately 0.95 lb. (0.43 kg.) each. In general, the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly 300 lb. as possible. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 in. in diameter, drilled in an iron plate $\frac{1}{4}$ in. in thickness, or weigh less than 0.75 lb. (0.34 kg.). Further, the small spheres shall be tested, by passing them over the above plate or by weighing, after every ten tests, and any which pass through or fall below the specified weight, shall be replaced by new spheres; provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

The iron composing these spheres shall have a chemical composition within the following limits:

Combined carbon	not	under	2.50	per cent
Graphitic carbon	"	over	0.25	"
Silicon	"	"	1.00	"
Manganese	"	"	0.50	"
Phosphorus	"	"	0.25	"
Sulfur	"	"	0.08	"

For each new batch of spheres used, the chemical analysis shall be furnished by the maker or be obtained by the user,

before introducing into the charge, and unless the analysis meets the above specifications, the batch of spheres shall be rejected.

THE OPERATION OF THE TEST.

10. *The Brick Charge.*—The number of bricks per test shall be ten for all bricks of so-called "block-size," whose dimensions fall between 8 and 9 in. in length, 3 and $3\frac{3}{4}$ in. in breadth, and $3\frac{3}{4}$ and $4\frac{1}{4}$ in. in thickness.[1] No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

11. *Speed and Duration of Revolution.*—The rattler shall be rotated at a uniform rate of not less than 29.5 nor more than 30.5 revolutions per minute, and 1800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin not to exceed ten revolutions will be allowed for stopping. Only one start and stop per test is generally acceptable. If, from accidental causes, the rattler is stopped and started more than once during a test, and the loss exceeds the maximum permissible under the specifications, the test shall be disqualified and another made.

12. *The Scales.*—The scales must have a capacity of not less than 300 lb., and must be sensitive to 0.5 oz., and must be tested by a standard test weight at intervals of not less than every ten tests.

13. *The Results.*—The loss shall be calculated in percentage of the initial weight of the brick composing the charge. In weighing the rattled brick, any piece weighing less than 1 lb. shall be rejected.

14. *The Records.*—A complete and continuous record shall be kept of the operation of all rattlers working under these specifications. This record shall contain the following data concerning each test made:

1. The name of the person, firm or corporation furnishing each sample tested.

2. The name of the maker of the brick represented in each sample tested.

[1] Where brick of larger or smaller sizes than the dimensions given above for blocks are to be tested, the same number of bricks per charge should be used, but allowance for the difference in size should be made in setting the limits for average and maximum rattler loss.

3. The name of the street, or contract, which the sample represented.
4. The brands or marks upon the bricks by which they were identified.
5. The number of bricks furnished.
6. The date on which they were received for test.
7. The date on which they were tested.
8. The drying treatment given before testing, if any.
9. The length, breadth and thickness of the bricks.
10. The collective weight of the ten large spherical shot used in making the test at the time of their last standardization.
11. The number and collective weight of the small spherical shot used in making the test, at the time of their last standardization.
12. The total weight of the shot charge, after its last standardization.
13. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel, and found them right at the beginning of the test.
14. Certificate of the operator of the number of charges tested since the last standardization of shot charge and last renewals of stave liners.
15. The time of the beginning and ending of each test, and the number of revolutions made by the barrel during the test, as shown by the indicator.
16. Certificate of the operator as to number of stops and starts made in each test.
17. The initial collective weight of the ten bricks composing the charge and their collective weight after rattling.
18. The loss calculated in percentage of the initial weight; and the calculation itself.
19. The number of broken bricks and remarks upon the portions which were included in the final weighing.
20. General remarks upon the test and any irregularities occurring in its execution.
21. The date upon which the test was made.
22. The location of the rattler and name of the owner, upon which the test was made.
23. The certificate of the operator that the test was made under the specifications of the American Society for Testing Materials and that the record is a true record.
24. The signature of the operator or person responsible for the test.
25. The serial number of the test.

In the event of more than one copy of the record of any test being required, they may be furnished on separate sheets, and marked duplicates, but the original record shall always be preserved intact and complete.

For the convenience of the public, the accompanying blank form, which provides space for the necessary data, is furnished and its use recommended.

Serial No.....

REPORT OF STANDARD RATTLER TEST OF PAVING BRICK.

IDENTIFICATION DATA.

Name of the firm furnishing sample.....
Name of the firm manufacturing sample.....
Street or job which sample represents.....
Brands or marks on the brick.....
Quantity furnished..... Drying treatment.....
Date received..... Date tested.....
Length..... Breadth..... Thickness.....

STANDARDIZATION DATA.

Weight of Charge. (After Standardization.)	Condition of Locknuts on Staves.	Condition of Scales.	Number and Position of Fresh Stave Liners.	Repairs. (Note any repairs affecting the condition of the barrel.)
10 Large spheres.....				
Small spheres.....				
Total.....				

Number of charges tested since last inspection.....

RUNNING DATA.

	Time Readings.			Revolution Counter Readings.	Running Notes, Stops, etc.
	Hours.	Minutes.	Seconds.		
Beginning of Test.....					
Final Reading.....					

WEIGHTS AND CALCULATIONS.

		Percentage Loss. (Note.—The Calculation Must Appear.)
Initial Weight of Ten Bricks.....		
Final Weight of Same.....		
Loss of Weight.....		

Number of broken bricks and remarks on same.....

I certify that the foregoing test was made under the specifications of the American Society for Testing Materials, and is a true record.

(Signature of Tester).....

Date.....

Location of Laboratory.....

ACCEPTANCE AND REJECTION OF MATERIAL.

15. *Basis of Acceptance or Rejection.*—Paving bricks shall not be judged for acceptance or rejection by the results of individual tests, but by the average of no less than five tests. Where a lot of bricks fail to meet the required average, it shall be optional with the buyer whether the bricks shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in Section 16.

16. *Range of Fluctuation.*—Some fluctuation in the results of the rattler test, both on account of variations in the bricks and in the machine used in testing, are unavoidable, and a reasonable allowance for such fluctuations should be made, wherever the standard may be fixed.

In any lot of paving brick, if the loss on a test computed upon its initial weight exceeds the standard loss by more than two per cent, then the portion of the lot represented by that test shall at once be resampled and three more tests executed upon it, and if any of these three tests shall again exceed by more than two per cent the required standard, then that portion of the lot shall be rejected.

If in any lot of brick, two or more tests exceed the permissible maximum, then the buyer may at his option reject the entire lot, even though the average of all the tests executed may be within the required limits.

17. *Fixing of Standards.*—The percentage of loss which may be taken as the standard, will not be fixed in these specifications, and shall remain within the province of the contracting parties. For the information of the public, the following scale of average losses is given, representing what may be expected of tests executed under the foregoing specifications:

	General Average Loss, per cent.	Maximum Permissible Loss, per cent.
For bricks suitable for heavy traffic.....	22	24
For bricks suitable for medium traffic.....	24	26
For bricks suitable for light traffic.....	26	28

Which of these grades should be specified in any given district and for any given purpose is a matter wholly within the province of the buyer, and should be governed by the kind

and amount of traffic to be carried, and the quality of paving bricks available.

18. *Culling and Retesting.*—Where, under Sections 15 and 16, a lot or portion of a lot of bricks is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may at his option permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete, the good portion shall be then resampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

19. *Payment of Cost of Testing.*—Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. (See also Section 23.) The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it, shall be paid by the seller, whether the material is finally accepted or rejected.

II. VISUAL INSPECTION.

It shall be the right of the buyer to inspect the bricks, subsequent to their delivery at the place of use, and prior to or during laying, to cull out and reject upon the following grounds:

20. All bricks which are broken in two or chipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where bricks are rejected upon this ground, it shall be the duty of the purchaser to use them so far as practicable in obtaining the necessary half-bricks for breaking courses and making closures, instead of breaking otherwise whole and sound bricks for this purpose.

21. All bricks which are cracked in such a degree as to produce defects such as are defined in Section 20, either from shocks received in shipment and handling, or from defective conditions of manufacture, especially in drying, burning or cooling, unless

such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

22. All bricks which are so off-size, or so misshapen, bent, twisted or kiln-marked, that they will not form a proper surface as defined by the paving specifications, or align with other bricks without making joints other than those permitted in the paving specifications.

23. All bricks which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between buyer and seller under this item, it shall be the right of the buyer to make two or more rattler tests of the brick which he wishes to exclude, as provided in Section 2, and if in either or both tests, the bricks fall beyond the maximum rattler losses permitted under the specifications, then all bricks having the same objectionable appearance may be excluded, and the seller shall pay for the cost of the test. But if under such procedure, the bricks which have been tested as objectionable, shall pass the rattler test, both tests falling within the permitted maximum, then the buyer cannot exclude the class of material represented by this test and he shall pay for the cost of the test.

24. All bricks which differ so markedly in color from the type or average of the shipment, as to make the resultant pavement checkered or disagreeably mottled in appearance. This Section shall not be held to apply to the normal variations in color which may occur in the product of one plant among bricks which will meet the rattler test as referred to in Sections 15, 16, and 17, but shall apply only to differences of color which imply differences in the material of which the bricks are made, or extreme differences in manufacture.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

PURITY OF RAW LINSEED OIL FROM NORTH AMERICAN SEED.

Serial Designation: D 1 – 15.

The specifications for this material are issued under the fixed designation D 1; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1915.

I. PROPERTIES AND TESTS.

Properties.

1. Raw linseed oil from North American seed shall conform to the following requirements:

	MAXIMUM.	MINIMUM.
Specific Gravity at $\frac{15°.5}{15°.5}$ C.	0.936	0.932
or		
Specific Gravity at $\frac{25°}{25°}$ C.	0.931	0.927
Acid Number	6.00	....
Saponification Number	195	189
Unsaponifiable matter, per cent	1.50	....
Refractive Index a 25° C.	1.4805	1.4790
Iodine Number (Hanus)	....	180

II. METHODS OF TESTING.

Methods of Testing.

2. The recommended methods of testing are as follows:

General.—All tests are to be made on oil which has been filtered at a temperature of between 60 and 80° F. through

paper in the laboratory immediately before weighing out. The sample should be thoroughly agitated before the removal of a portion for filtration or analysis.

Specific Gravity.—Use a pyknometer, accurately standardized and having a capacity of at least 25 cc., or any other equally accurate method, making a test at 15°.5 C., water being 1 at 15°.5 C., or a test at 25° C., water being 1 at 25° C.

Acid Number.—Expressed in milligrams of KOH per gram of oil. Follow the method described in Bulletin No. 107, revised 1908, Department of Agriculture, Bureau of Chemistry, page 142.

Saponification Number.—Expressed as with Acid Number. Blanks should also be run to cover effect of alkali in glass. Follow method given in Bulletin No. 107, revised 1908, Department of Agriculture, Bureau of Chemistry, pages 137–138.

Unsaponifiable Matter.—Follow Boemer's method taken from his Ubbelohde Handbuch Der Ole u. Fette, pages 261–262. "To 100 g. of oil in a 1000 to 1500-cc. Erlenmeyer flask add 60 cc. of an aqueous solution of potassium hydroxide (200 g. KOH dissolved in water and made up to 300 cc.) and 140 cc. of 95-per cent alcohol. Connect with a reflux condenser and heat on the water bath, shaking at first until the liquid becomes clear. Then heat for one hour with occasional shaking. Transfer while yet warm to a 2000-cc. separatory funnel to which some water has been added, wash out the Erlenmeyer with water using in all 600 cc. Cool, add 800 cc. of ether and shake vigorously one minute. In a few minutes the ether solution separates perfectly clear. Draw off the soap and filter the ether (to remove last traces of soap) into a large Erlenmeyer and distill off the ether, adding if necessary one or two pieces of pumice stone. Shake the soap solution three times with 400 cc. of ether, which add to the first ether extract. To the residue left after distilling the ether add 3 cc. of the above KOH solution, and 7 cc. of the 95-per cent alcohol, and heat under reflux condenser for 10 minutes on the water bath. Transfer to a small separatory funnel, using 20 to 30 cc. of water, and after cooling shake out with two portions of 100 cc. of ether; wash the ether three times with 10 cc. of water. After drawing off the last of the water, filter the ethereal solution so as to remove the last drops of water, distill off the ether, dry residue in water oven and weigh."

Or, any accurate method involving the extraction of the dried soap may be used.

Refractive Index.—Use a properly standardized Abbé Refractometer at 25° C., or any other equally accurate instrument.

Iodine Number (*Hanus*).—Follow the Hanus method as described in Bulletin No. 107, revised 1908, Department of Agriculture, Bureau of Chemistry, page 136.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD SPECIFICATIONS

FOR

YELLOW-PINE BRIDGE AND TRESTLE TIMBERS.

TO BE APPLIED TO SOLID MEMBERS AND NOT TO COMPOSITE MEMBERS.

Serial Designation: D 10 – 15.

The specifications for this material are issued under the fixed designation D 10; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1910; REVISED, 1915.

I. GENERAL REQUIREMENTS.

1. Except as noted, all timber shall be cut from sound trees and sawed standard size; close-grained and solid; free from defects such as injurious ring shakes and crooked grain; unsound knots; knots in groups; decay; large pitch pockets, or other defects that will materially impair its strength.

Dense Southern Yellow Pine.

2. (*a*) Dense southern yellow pine shall show on either end an average of at least six annual rings per inch and at least one-third summer wood, or else the greater number of the rings shall show at least one-third summer wood, all as measured over the third, fourth, and fifth inches on a radial line from the pith. Wide-ringed material excluded by this rule will be acceptable, provided that the amount of summer wood as above measured shall be at least one-half.

(*b*) The contrast in color between summer wood and spring wood shall be sharp and the summer wood shall be dark in color, except in pieces having considerably above the minimum requirement for summer wood.

(*c*) In cases where timbers do not contain the pith, and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over 3 in. on an approximate radial line beginning at the edge nearest the pith in timbers over 3 in. in thickness and on the second inch (on the piece) nearest to the pith in timbers 3 in. or less in thickness.

(*d*) In dimension material containing the pith but not a 5-in. radial line, which is less than 2 by 8 in. in section or less than 8 in. in width, that does not show over 16 sq. in. on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a 5-in. radial line the inspection shall apply to the three inches farthest from the pith.

(*e*) The radial line chosen shall be representative. In case of disagreement between purchaser and seller the average summer wood and number of rings shall be the average of the two radial lines chosen.

Sound Southern Yellow Pine.

3. Sound southern yellow pine shall include pieces of southern pine without any ring or summer-wood requirement.

Standard Size of Sawed Timber.

4. Rough timbers when sawed to standard size, shall mean that they shall not be over $\frac{1}{4}$ in. scant from actual size specified. For instance, a 12 by 12-in. timber shall measure not less than $11\frac{3}{4}$ by $11\frac{3}{4}$ in.

Standard Dressing of Sawed Timber.

5. Standard dressing means that not more than $\frac{1}{4}$ in. shall be allowed for dressing each surface. For instance, a 12 by 12-in. timber shall, after dressing four sides, not measure less than $11\frac{1}{2}$ by $11\frac{1}{2}$ in.

II. STRINGERS.

Stringers.

6. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show not less than 80 per cent of heart on each of the four sides, measured across the sides anywhere in the length of the piece; loose knots, or knots greater than $1\frac{1}{2}$ in. in diameter, will not be permitted at points within 4 in. of the edges of the piece.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged, except it may have 1 in. wane on one corner. Knots shall not exceed in their largest diameter one-fourth the width of the face of the stick in which they occur. Ring shakes extending not over one-eighth of the length of the piece are admissible.

III. CAPS AND SILLS.

Caps and Sills.

7. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show 85 per cent of heart on each of the four sides, measured across the sides anywhere in the length of the piece, and shall be free from knots over $2\frac{1}{2}$ in. in diameter. Knots shall not be in groups.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged, except it may have 1 in. wane on one corner, or $\frac{1}{2}$ in. wane on two corners. Knots shall not exceed in their largest diameter one-fourth the width of the face of the stick in which they occur. Ring shakes shall not extend over one-eighth of the length of the piece.

IV. POSTS.

Posts.

8. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show not less than 75 per cent of heart, measured across the face anywhere on the length of the piece, and shall be free from knots over $2\frac{1}{2}$ in. in diameter. Knots shall not be in groups.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged, except it may have 1 in. wane on one corner, or $\frac{1}{2}$ in. wane on two corners. Knots shall not exceed in their largest diameter one-fourth the width of the face of the stick in which they occur. Ring shakes shall not extend over one-eighth of the length of the piece.

V. LONGITUDINAL STRUTS OR GIRTS.

Longitudinal Struts or Girts.

9. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show one face all heart; the other face and two sides shall show not less than 85 per cent of heart, measured across the face or side anywhere in the piece, and shall be free from knots $1\frac{1}{2}$ in. or over in diameter.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged and sound, and shall be free from knots $1\frac{1}{2}$ in. or over in diameter.

VI. LONGITUDINAL X-BRACES, SASH BRACES AND SWAY BRACES.

Longitudinal X-Braces, Sash Braces and Sway Braces.

10. (*a*) *Dense Southern Yellow Pine.*—Dense southern yellow pine shall show not less than 80 per cent of heart on two faces and four square edges, and shall be free from knots over $1\frac{1}{2}$ in. in diameter.

(*b*) *Sound Southern Yellow Pine.*—Sound southern yellow pine shall be square-edged and sound, and shall be free from knots $2\frac{1}{2}$ in. or over in diameter.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD TEST FOR ABRASION OF ROAD MATERIAL.

Serial Designation: D 2 – 08.

This test is issued under the fixed designation D 2; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1908.

This well-known test is similar in almost all respects to the Deval abrasion test of the French School of Roads and Bridges. It has been used since 1878, and is entirely satisfactory for the purpose for which it was designed.

ABRASION TEST.

The machine shall consist of one or more hollow iron cylinders; closed at one end and furnished with a tightly fitting iron cover at the other; the cylinders to be 20 cm. in diameter and 34 cm. in depth, inside. These cylinders are to be mounted on a shaft at an angle of 30 deg. with the axis of rotation of the shaft.

At least 30 lb. of coarsely broken stone shall be available for a test. The rock to be tested shall be broken in pieces as nearly uniform in size as possible, and as nearly 50 pieces as possible shall constitute a test sample. The total weight of

rock in a test shall be within 10 g. of 5 kg. All test pieces shall be washed and thoroughly dried before weighing. Ten thousand revolutions, at the rate of between 30 and 33 per minute, shall constitute a test. Only the percentage of material worn off which will pass through a 0.16-cm. ($\frac{1}{16}$-in.) mesh sieve shall be considered in determining the amount of wear. This may be expressed either as the percentage of the 5 kg. used in the test, or the French coefficient, which is in more general use, may be given; that is, coefficient of wear $= 20 \times \frac{20}{w} = \frac{400}{w}$, where w is the weight in grams of the detritus under 0.16 cm. ($\frac{1}{16}$ in.) in size per kilogram of rock used.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD DEFINITIONS

OF

TERMS RELATING TO STRUCTURAL TIMBER.

Serial Designation: D 9 – 15.

These definitions are issued under the fixed designation D 9; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1907; REVISED, 1915.

I. DEFINITION OF STRUCTURAL TIMBER.

By the term "Structural Timber" is understood all such products of wood in which the strength of the timber is the controlling element in their selection and use. The following is a list of products which are recommended for consideration as structural timbers:

Trestle Timbers.—Stringers, caps, posts, mud sills, bracing, bridge ties, guard rails.

Car Timbers.—Car framing, including upper framing; car sills.

Framing for Buildings.—Posts, mud sills, girders, framing joists.

Ship Timbers.—Ship timbers, ship decking.

Cross Arms for Poles.

II. STANDARD DEFECTS.

Measurements which refer to the diameter of knots or holes should be considered as referring to the mean or average diameter,

1. *Sound Knot.*—A sound knot is one which is solid across its face and which is as hard as the wood surrounding it; it may be either red or black, and is so fixed by growth or position that it will retain its place in the piece.

2. *Loose Knot.*—A loose knot is one not firmly held in place by growth or position.

3. *Pith Knot.*—A pith knot is a sound knot with a pith hole not more than $\frac{1}{4}$ in. in diameter in the center.

4. *Encased Knot.*—An encased knot is one whose growth rings are not intergrown and homogeneous with the growth rings of the piece it is in. The encasement may be partial or complete; if intergrown partially or so fixed by growth or position that it will retain its place in the piece, it shall be considered a sound knot; if completely intergrown on one face, it is a watertight knot.

5. *Rotten Knot.*—A rotten knot is one not as hard as the wood it is in.

6. *Pin Knot.*—A pin knot is a sound knot not over $\frac{1}{2}$ in. in diameter.

7. *Standard Knot.*—A standard knot is a sound knot not over $1\frac{1}{2}$ in. in diameter.

8. *Large Knot.*—A large knot is a sound knot, more than $1\frac{1}{2}$ in. in diameter.

9. *Round Knot.*—A round knot is one which is oval or circular in form.

10. *Spike Knot.*—A spike knot is one sawn in a lengthwise direction; the mean or average width shall be considered in measuring these knots.

11. *Pitch Pockets.*—Pitch pockets are openings between the grain of the wood containing more or less pitch or bark. These shall be classified as *small, standard* and *large* pitch pockets.

(*a*) *Small Pitch Pocket.*—A small pitch pocket is one not over $\frac{1}{8}$ in. wide.

(*b*) *Standard Pitch Pocket.*—A standard pitch pocket is one not over $\frac{3}{8}$ in. wide, or 3 in. in length.

(*c*) *Large Pitch Pocket.*—A large pitch pocket is one over $\frac{3}{8}$ in. wide, or over 3 in. in length.

12. *Pitch Streak.*—A pitch streak is a well-defined accumulation of pitch at one point in the piece. When not sufficient

to develop a well-defined streak, or where the fiber between grains, that is, the coarse-grained fiber, usually termed "spring wood," is not saturated with pitch, it shall not be considered a defect.

13. *Wane.*—Wane is bark, or the lack of wood from any cause, on edges of timbers.

14. *Shakes.*—Shakes are splits or checks in timbers which usually cause a separation of the wood between annual rings.

15. *Rot, Dote and Red Heart.*—Any form of decay which may be evident either as a dark red discoloration not found in the sound wood, or the presence of white or red rotten spots, shall be considered as a defect.

16. *Ring Shake.*—An opening between the annual rings.

17. *Through Shake.*—A shake which extends between two faces of a timber.

III. STANDARD NAMES FOR STRUCTURAL TIMBERS.

1. *Southern Yellow Pine.*—This term includes the species of yellow pine growing in the southern states from Virginia to Texas, that is, the pines hitherto known as longleaf pine (*Pinus palustris*), shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), Cuban pine (*Pinus heterophylla*) and pond pine (*Pinus serotina*).

Under this heading, two classes of timber are designated: (*a*) dense southern yellow pine and (*b*) sound southern yellow pine. It is understood that these two terms are descriptive of quality rather than of botanical species.

(*a*) Dense southern yellow pine shall show on either end an average of at least six annual rings per inch and at least one-third summer wood, or else the greater number of the rings shall show at least one-third summer wood, all as measured over the third, fourth, and fifth inches on a radial line from the pith. Wide-ringed material excluded by this rule will be acceptable, provided that the amount of summer wood as above measured shall be at least one-half.

The contrast in color between summer wood and spring wood shall be sharp and the summer wood shall be dark in color, except in pieces having considerably above the minimum requirement for summer wood.

FIG. 1.—Loose Knot.

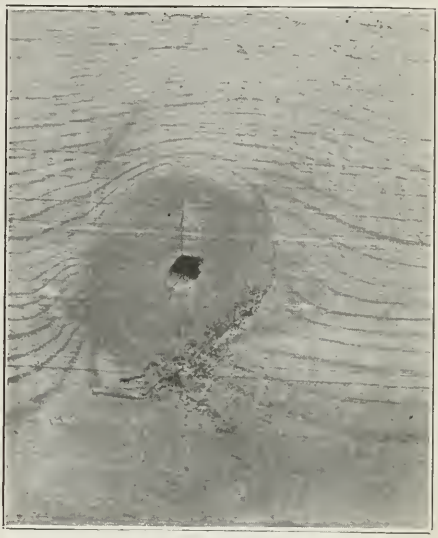


FIG. 2.—Pith Knot.

FIG. 3.—Encased Knot.

FIG. 4.—Rotten Knot.

STANDARD DEFINITIONS OF TERMS RELATING TO STRUCTURAL TIMBER.

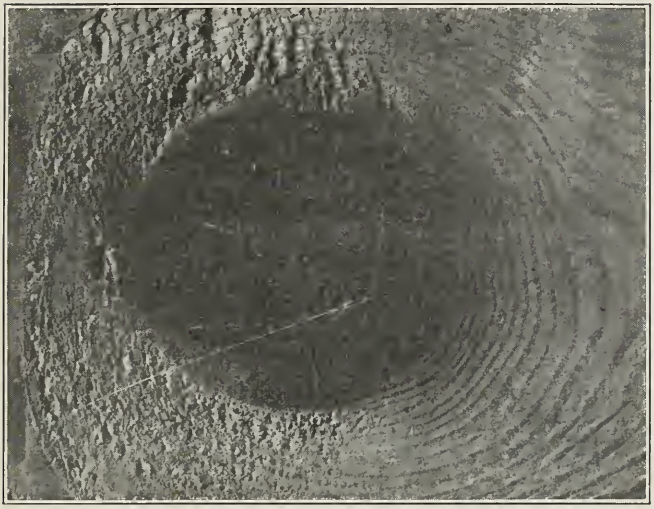


FIG. 6.—Standard Knot.

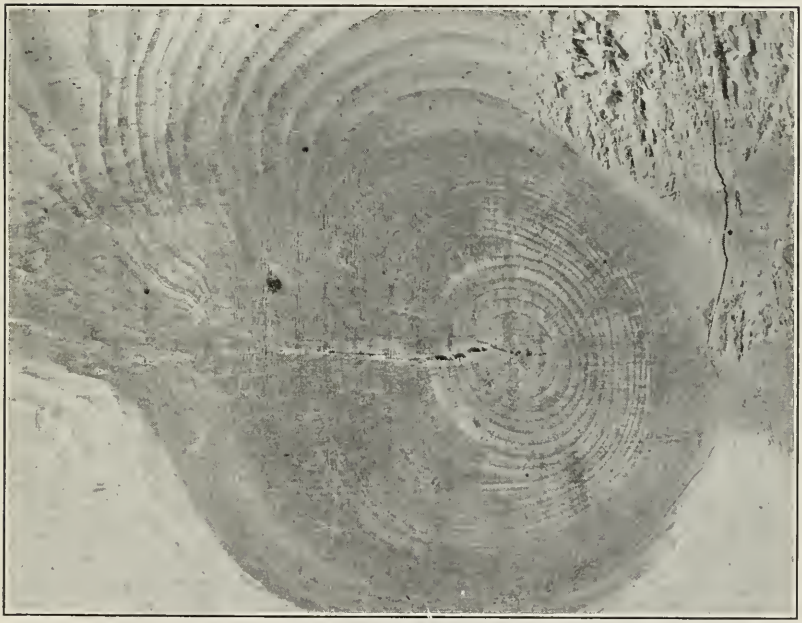


FIG. 7.—Large Knot.

STANDARD DEFINITIONS OF TERMS RELATING TO STRUCTURAL TIMBER.

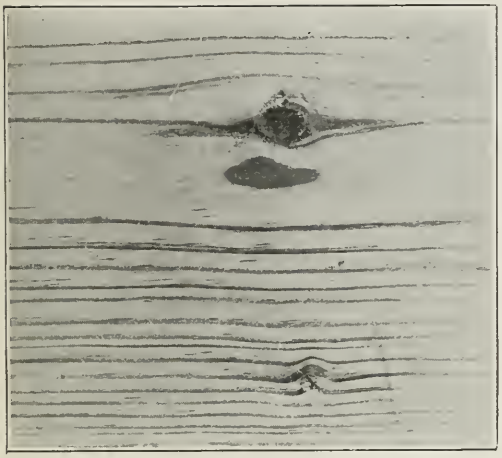


FIG. 5.—Pin Knot.

FIG. 8.—Spike Knot.

FIG. 9.—Pitch Pocket.

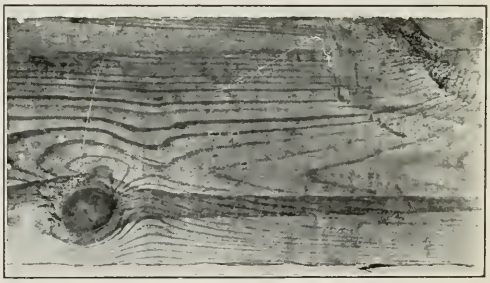


FIG. 10.—Pitch Streak

(*b*) Sound southern yellow pine shall include pieces of southern pine without any ring or summer-wood requirement.

2. *Douglas Fir.*—The term "Douglas Fir" is to cover the timber known likewise as yellow fir, red fir, western fir, Washington fir, Oregon or Puget Sound fir or pine, norwest and west coast fir.

3. *Norway Pine*, to cover what is known also as "Red Pine."

4. *Hemlock*, to cover Southern or Eastern hemlock; that is, hemlock from all States east of and including Minnesota.

5. *Western Hemlock*, to cover hemlock from the Pacific coast.

6. *Spruce*, to cover Eastern spruce; that is, the spruce timber coming from points east of and including Minnesota.

7. *Western Spruce*, to cover the spruce timber from the Pacific coast.

8. *White Pine*, to cover the timber which has hitherto been known as white pine, from Maine, Michigan, Wisconsin and Minnesota.

9. *Idaho White Pine*, the variety of white pine from western Montana, northern Idaho, and eastern Washington.

10. *Western Pine*, to cover the timber sold as white pine coming from Arizona, California, New Mexico, Colorado, Oregon and Washington. This is the timber sometimes known as "Western Yellow Pine," or "Ponderosa Pine," or "California White Pine," or "Western White Pine."

11. *Western Larch*, to cover the species of larch or tamarack from the Rocky Mountain and Pacific coast regions.

12. *Tamarack*, to cover the timber known as "Tamarack," or "Eastern Tamarack," from States east of and including Minnesota.

13. *Redwood*, to include the California wood usually known by that name.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS.

STANDARD METHODS

FOR

TESTING.

Serial Designation: E 1–16.

These methods are issued under the fixed designation E 1; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

I. ADOPTED, 1910; REVISED, 1916.
II. ADOPTED, 1910; REVISED, 1916.
III. ADOPTED, 1911.
IV. ADOPTED, 1915.
V. ADOPTED, 1910.

I. METHODS FOR TENSION TESTS OF METALS.

1. *Definition of Terms.*

Elastic Limit is the greatest load per unit of original cross-section which does not produce a permanent set.

This determination is rarely made in the commercial testing of materials.

Proportional Limit is the load per unit of original cross-section at which the deformations cease to be directly proportional to the loads.

This determination is rarely made in the commercial testing of materials.

Yield Point is the load per unit of original cross-section at which a marked increase in the deformation of the specimen occurs without increase of load. It is usually determined by

the drop of the beam of the testing machine, or by the use of dividers.

2. Information obtained from the various laboratories in which tension tests are made shows that in many cases the forms and dimensions of specimens as recommended by the American Society for Testing Materials are in use, and that in other cases these forms and dimensions most nearly reconcile the differences that exist between the various forms employed.

3. It is therefore recommended that the selection of specimens, and their forms and dimensions, shall conform to the specifications for each material, as are now adopted by the American Society for Testing Materials.

In the case of flats $\frac{1}{4}$ in. or under in thickness, the dimensions shall be as follows: Width equal to 5 times the thickness of the specimen, except that in no case shall the width be less than $\frac{3}{4}$ in.; gage length equal to 24 times the thickness of the specimen, except that in no case shall the gage length be less than 2 in.

4. It is believed that the distance between the end of gage length and beginning of shoulders, as prescribed in the standard specifications of the American Society for Testing Materials, is ample to avoid interference with proper elongation, and no grounds are found for recommending any change.

5. All information obtained confirms the investigations of Committee O (since dissolved), to the effect that within the limits of speed common in commercial testing, the effect of different speeds on results is not of observable moment; that is, within ranges of speed varying from 1 to 6 in. per minute.

6. Beyond these limits, however, very rapid loading influences the ultimate strength, which increases with the speed. Whether the elongation is increased or decreased depends somewhat upon the nature of the material, though in general, very rapidly applied loads will increase the stretch, owing to the elongation occurring over the whole body of the specimen, rather than chiefly at the point of reduction, which is more marked with slowly applied loads.

7. Within the limits of speed customary in determining the modulus of elasticity, it does not appear that the rate of loading influences the value obtained, but whether this value be deter-

mined by an autographic attachment to the machine, or by an extensometer on the specimen, it is desirable that the loading be not too rapid, or not over 0.05 in. per minute, to avoid impairing the accuracy of the sensitive devices employed.

8. In determining the modulus of elasticity, the elastic limit, and the proportional limit, the extensometer should be attached to at least two sides of the specimen, to compensate for unequal elongation, for improper holding, or for any slight bending that may exist in the specimen.

9. All authorities seem to regard it as desirable to measure the elongation on two or more sides of the test specimen, and most extensometers provide for so doing.

10. The greatest accuracy is required in determining the modulus of elasticity, since small errors in measuring elongation are of considerable consequence in the result.

11. Since the modulus is determined for points well within the elastic limit, the total elongation to be measured is much smaller than at the elastic limit.

12. The elastic limit should be determined with great care, but any inaccuracy will cause less proportionate error than in the case of the modulus. The yield point, being less well defined, cannot be so closely determined, and it is believed that in most cases the use of dividers instead of an extensometer will give sufficiently accurate results.

13. It is considered undesirable in accurate determinations of the modulus of elasticity to use a shorter gage length than 8 in. It is evident that the greater the total elongation measured, the less will be the error due to inaccuracy of the reading, and the accuracy thus appears to increase directly as the gage length.

14. That the difference between short and long gage lengths has a greater influence in affecting results than other factors (personal error, inaccuracy of the testing machine, etc.), is shown by the closely agreeing readings obtained with the greater lengths.

15. The effect of improper methods of holding specimens could not be established from the results of actual tests. The result of improper methods of gripping materials of low elongation, such as cast iron, is well known, and it is probable that in material of a more ductile nature, the effect is largely local and does not extend to the portion of the specimen within the gage marks.

CONDITIONS TO ENSURE CORRECT TESTING MACHINES.

16. It is recommended that in machines on which specimen tests are made, whether the power be applied hydraulically or by means of screws and gears, the load be measured by a separate system of levers and knife edges, or by a method similar to that employed in the Emery testing machines.

17. All knife edges shall be kept sharp, and free from oil and dirt, and the machine shall be sensitive to a variation in load of one two-hundred-and-fiftieth of the load carried. Design and workmanship on testing machines shall be good, and they shall be calibrated at least once every six months by the following method:

CALIBRATION OF TESTING MACHINES.

18. Test for accuracy by loading the weighing table with standard weights, and compare the actual weight at each addition with the reading of the beam. If the table is uniformly loaded in this manner with the full amount of weights that it will accommodate, the proportionality of the levers and the weighing beam can be successfully established. This relation, in a properly designed machine, will remain constant for all loads, but as a further test for sensitiveness under greater loads than can be accommodated in this manner, the following procedure is recommended:

19. Place in the machine a tension bar of such cross-section that the maximum capacity will not stress it to the elastic limit. Stress this bar to various extents through the full range of the machine, and at each load balance the beam and place upon the weighing table standard weights of 100 lb. A weight one two-hundred-and-fiftieth of the total load on the machine should produce a readable movement of the beam.

20. Where evidence of the accuracy of the machine over its whole range is desired, a known load may be applied by means of an extensometer and calibrated bar, whose modulus of elasticity has been determined with exactness.

21. It is recommended that a device be adopted conforming to the following requirements, in which the extensometer and bar are permanently attached to each other:

(*a*) The bar shall be of high-elastic-limit material, and of such cross-section that this limit will be well above the total capacity of the machine on which it is to be used.

(*b*) This bar shall be annealed or otherwise treated so as to eliminate internal or unequal stress in the material, and to ensure its elastic modulus being uniform for successive tests.

(*c*) The extensometer shall be permanently attached to the bar, and shall measure the elongation on two opposite sides.

(*d*) The extensometer shall be preferably of the indicating or direct-reading type, and shall indicate to ten-thousandths of an inch or less.

(*e*) The method of securing the bar in the drawheads of the machine shall be positive and without slip, and shall ensure its axial location.

(*f*) The length of the bar measured by the extensometer shall be sufficient that the smallest extensometer division, that is, 0.0001 in., shall correspond to a difference in loading of 0.2 per cent of the capacity of the machine, or less.

(*g*) The extensometer shall be protected from injury by a permanently attached case with cover removable for reading the scale.

(*h*) The apparatus shall be plainly marked with the maximum load that can be safely applied without injury.

(*i*) The apparatus shall itself be calibrated either by the United States Bureau of Standards, or in a manner that will ensure equally trustworthy results.

METHODS OF GRIPPING TEST SPECIMENS.

22. It is recommended that for specimens of rolled material, serrated grips, flat and V-shaped, be adopted, the former for rectangular and the latter for round specimens. Serrated grips with curved faces appear to have no advantage, and to cause crushing of the material.

23. Wedges with ball and socket do not seem to be necessary, and for commercial testing their use has been generally discontinued.

24. Specimens of turned form, with threaded ends, should be secured in such a manner that side bending stresses are avoided.

25. It is considered important for correct results that the specimen be located in the exact center of the heads, and to better secure this condition, the openings in the heads should be lined up with each other by means of a plumb-bob and be tested for parallelism with a spirit level. Each pair of packing pieces and wedges that are to be used together in the same head should correspond exactly in thickness and other dimensions, and the wedges should be inserted an equal distance when the specimen is in place.

SELECTION AND PREPARATION OF SPECIMEN.

26. Specimens representative of steel castings may be cut from the bottom of a sink head or riser, or from a coupon attached to the casting. In either case the part from which the specimen is taken should be relatively large in proportion to the size of the casting and should be annealed with it.

27. Workmanship on specimens shall be of the most careful nature, and surfaces should be free from nicks and tool marks. All wire edges should be removed and corners generously rounded.

28. If specimens of rolled material are sheared in the rough from sections, at least $\frac{1}{8}$ in. of the material should be removed from the sheared edges in machining.

GENERAL REQUIREMENTS FOR THE MEASURING OF ELONGATION.

29. In determining the modulus of elasticity and the elastic limit, it is recommended that when practicable the elongation be measured in a length not less than 8 in., and that the following requirements be provided for:

(*a*) The specimen shall be round in section, finished as smooth as possible, and shall be provided with threaded ends for attachment to the draw-heads of the machine.

(*b*) The specimen shall be placed in the exact center of the heads, and be secured in some positive manner, so that slip and side bending stresses do not occur.

(*c*) The extensometer should be of a type to measure the elongation on two or more sides of the specimen.

(*d*) It should read to 0.0001 in. or less.

(*e*) It should be of such a design that no change of zero will occur upon release of the load in determining the real elastic limit.

(*f*) The load shall be applied so slowly that simultaneous readings of elongation and load can be obtained with certainty.

(*g*) The testing machine shall have previously been calibrated for accuracy and sensitiveness, and heads lined up and made parallel.

II. METHODS FOR COMPRESSION TESTS OF METALS.

1. *Definition of Terms.*

Elastic Limit is the greatest load per unit of original cross-section which does not produce a permanent set.

This determination is rarely made in the commercial testing of materials.

Proportional Limit is the load per unit of original cross-section at which the deformations cease to be directly proportional to the loads.

This determination is rarely made in the commercial testing of materials.

Yield Point is the load per unit of original cross-section at which a marked increase in the deformation of the specimen occurs without increase of load. It is usually determined by the drop of the beam of the testing machine, or by the use of dividers.

2. The test specimen shall be a cylinder having plane ends truly normal to its axis.

Only two replies from testing laboratories mention cubes. A cylindrical specimen will usually be cheaper to prepare than a cube. The stresses are probably less uniformly distributed over a square than over a circular section, owing to the influence of the corners, this being especially the case with the internal shearing stresses which accompany the compression.

3. The diameter of the specimen shall be not less than 1 in. nor greater than 1.13 in. A specimen 1 in. in diameter is to be preferred.

The range of diameter mentioned in the replies from testing laboratories is from 1 in. to 1.129 in. A diameter of 1.1284 in. gives a section area of 1 sq. in.

4. The length of the specimen should be between 2.5 and 4 diameters.

Two testing laboratories use a length of 1 diameter, one a length of from 1.5 to 2 diameters, one a length of 2.6 diameters, and one a length of 10.5 diameters. It is believed that a length less than 2.5 diameters is not sufficient for the internal shear to be properly developed, and that such short lengths give a fictitious strength owing to the friction of the bearing plates of the machine, which causes the specimen to assume a barrel-like form.

5. No bedding should be used for the ends of the specimen.

Only one reply favors bedding. It is known by general experience that bedding modifies the breaking load and that different kinds of bedding have different influences.

6. The bearing blocks which transmit the pressure from the testing machine should be truly normal to the plane ends of the specimen. To secure this, one of the blocks should be provided with a hemispherical bearing which can turn freely.

These requirements seem essential in order that the load may not be eccentrically applied to the specimen, and are generally recommended in the replies from testing laboratories.

7. The speed of compression should be slow, not exceeding 0.1 in. per minute. Near the elastic limit and yield point, the load should be increased very slowly.

A lower speed than that stated might be advisable if permitted by the testing machine. Evidently a higher speed may be allowed with a long specimen than with a short one.

8. For determining modulus of elasticity, the linear compression of the specimen should be observed by a precise compressometer which is attached to the specimen and does not touch the bearing blocks of the machine. Readings of the compressometer should be taken for three loads, the first at about one-fourth, the second at about one-half, and the third at about three-fourths of the elastic limit.

It is believed that these measurements are sufficient for most commercial work. Nothing is said about the release of the specimen from load, since opinions differ as to its advisability.

9. To determine the elastic and also the proportional limit, several readings of the compressometer should be taken as that limit is approached for load increments of 1000 lb. per sq. in.

This requirement seems sufficient to determine the proportional limit for materials in which such a limit exists. It does not seem wise to require the first permanent set to be observed for ordinary commercial work.

10. The yield point is to be noted as corresponding to that load for which the compressometer shows a linear compression without an increase in load. In the absence of a compressometer this point may be noted, for ductile materials, by the drop of the scale beam.

This requirement corresponds to the usual practice of testing laboratories. It is regarded as important that the term "elastic limit" should not be used to designate the yield point.

11. Measurements for the modulus of elasticity, elastic limit, proportional limit, and yield point may be made, if desired, on a specimen ranging in length from 10 to 15 diameters.

This clause is inserted because it may often be difficult to apply a compressometer in a length shorter than 4 in.

12. The record of the test should mention any phenomena observed near the elastic limit, proportional limit, and yield point. The manner of final failure should also be noted when the test is carried to this limit.

This requirement furnishes data for comparing the behavior of brittle and ductile metals near critical points of molecular change.

III. METHODS FOR TRANSVERSE TESTS OF METALS.

1. In the case of cast metals, when transverse tests are to be used to aid in determining the quality of the material, the specimen used shall be cast vertical, shall be $1\frac{1}{4}$ in. in diameter, and long enough to use a span of at least 15 times the diameter.

It is important that a definite and uniform standard be adopted so that the results may be comparable with each other; hence the diameter specified above (sectional area corresponding to practically one square inch). The determination of span is at present the subject of international tests to decide upon a definite distance to replace the present standard of 12 in. It will probably be 16 to 18 in.

The circular section will best secure a uniform thickness of skin, and thus avoid this irregularity when other sections are employed.

In the case of ductile materials (except in impact tests) transverse tests shall never be used to determine the quality of the material, tension tests being those suitable for the purpose.

In small round or square bars of ductile material, both the modulus of rupture and the transverse elastic limit vary considerably with the span.

In the case of tests made for determining constants to be used for designing, the specimen shall conform as nearly as possible with the form and size of the piece to be used. Thus, if I or T-sections are to be used, the specimens shall be of I or T-section. In the case of flat springs or plate glass, they shall be flat; in the case of timber, rectangular; etc.

It is well known that the modulus of rupture varies with the shape of the section, being very much greater in the case of round than in I-sections. Hence the modulus of rupture suitable for use for one would be entirely unsuitable for the other.

In rolled sections, the smaller ones are subjected to a more thorough working in the process of rolling than the larger.

2. In the case of the "Arbitration Bar" adopted for cast iron, the span has been fixed at 12 in., but may be extended as above stated. The bar will serve for cast and brittle materials.

In the case of ductile materials, when the modulus of rupture is desired, the span shall generally be less than 12 or 15 times the depth. Exceptions, however, occur, as in flat springs and in some cases in full-size pieces, when the spans and methods of supporting the ends, etc., shall conform to the conditions of service.

3. In the case of cast and brittle metals, the speed of testing shall not exceed 0.2 in. per minute. For other specimens the speed shall be correspondingly low.

4. The preparation of the specimen shall be such that it truly represents the material itself. The introduction of extra-

neous influences should be avoided as far as the knowledge of the material will permit. Thus, in cast metals no coupons shall be used; cast materials for tests shall go into dry molds standing vertical.

No specimen shall be machined before testing, except when information is specifically desired regarding the strength of such machined specimens.

5. The transverse yield point for ductile materials shall be noted approximately by the drop of the scale beam.

6. If the transverse elastic limit is to be determined for comparison with that obtained in the tensile test, the successive increments of load in the neighborhood of the transverse elastic limit shall be comparatively small, and after each load has been applied and the corresponding deflection measured by means of the deflectometer, the load shall be removed and the deflection measured again to determine the permanent set.

In those cases where the arbitration bar is used for such cast materials as have an elastic limit, the increment of load used near the transverse elastic limit shall be 250 lb.

It is well known that when the transverse elastic limit is determined, of course by means of a transverse test, the extreme fiber stress at this transverse elastic limit is not the same as that at the tensile elastic limit of the material; and moreover, that it varies with both the section and the span; hence the desirability of comparing the transverse elastic limit with the tensile elastic limit.

7. In the case of ductile materials, the arrangement of the supports shall be such that longitudinal tension in the specimen due to the rigidity of the supports is avoided.

8. In the case of ductile materials, special care shall be used when determining the ultimate load. For this purpose it will be necessary when approaching the ultimate (that is, the maximum) load, to make the speed of testing slow enough to enable the observer to note the maximum load.

In many cases, as in I and T-beams, the maximum load can be easily ascertained, while in others, such as round or flat sections with short spans, it may not be possible to determine it exactly; but it will almost always be possible to determine it with sufficient accuracy for all practical purposes.

IV. METHODS FOR BRINELL HARDNESS TESTS OF METALS.

Chemical Composition and Heat Treatment of Balls.

1. The chemical composition, as far as carbon and chromium are concerned, should be from 1 to 1.2 per cent of carbon, and from 1 to 1.5 per cent of chromium.

2. The heat treatment should be such as will result in making the balls as hard as possible, consistent with the ability to resist the pressure without cracking or crushing.

While a long series of careful experiments would be needed to justify the specifications of more exact conditions in these regards, and while some users of these tests think that the chemical composition (within limits) plays a very small part, if any, in the problem, it is believed that the above requirements will be found satisfactory for commercial work, until such time as suitable experiments shall have furnished the data necessary for making the conditions more precise.

Diameter and Form of Balls.

3. The standard diameter of balls should be 10 mm. with a permissible variation of 0.0025 mm. (0.0001 in.) plus or minus; no ball either new or old showing a greater variation is to be employed. The standard diameter should always be employed, except in very rare cases when some other is absolutely necessary. If, at any time in testing, a hardness of No. 600 be exceeded, the balls should be remicrometered.

Thus far there is not sufficient evidence to show that the hardness numbers will be the same when different diameters of balls are used, and some of the evidence indicates that the reverse is the case; hence the importance of adhering to one size of ball.

Pressure.

4. The standard pressures used should be 3000 kg. for steel, and 500 kg. for softer metals. Departure from these pressures should never be tolerated, except in rare cases where it is unavoidable. The time of pressure should be at least 30 seconds.

The fact that, with our present light on the subject, we can only regard the results as comparative, renders it important to employ as few different pressures as possible.

MEASUREMENT OF DIAMETER OR DEPTH OF INDENTATION.

5. Whether the diameter or the depth of the indentation is measured, apparatus should be used that will give results as accurately as a microscope mounted on, and moved by, a micrometer screw.

As to the choice between the two, there exists a very decided difference of opinion, some thinking one and some the other more conducive to accuracy. The source of error in either case (assuming the measuring apparatus to be accurate) is the depression or the elevation of the metal immediately surrounding the indentation.

V. METHODS FOR METALLOGRAPHIC TESTS OF METALS.

MICROSCOPIC EXAMINATION.

For unhardened iron and steel, the following process has given satisfaction:

1. After polishing, examine under a magnification of 50 to 150 diameters. Look for slag or cinder in wrought iron, manganese sulphide, etc., in steel,[1] and size and shape of graphite in cast iron.

2. Etch with a saturated solution of picric acid in alcohol for 15 seconds. This reveals the pearlite[2] by turning it darker than the accompanying ferrite or cementite. In wrought iron, any pearlite present shows up, and the general appearance will sometimes show whether the material was puddled, etc., or made from reheated scrap. Those who wish to bring out the ferrite grains can do so easily and quickly by etching with nitric acid. To this end, nitric acid of 1.42 specific gravity should be diluted with either:

(*a*) 90 parts by volume of water to 10 of acid,
(*b*) 75 " " " " " " 25 " " or preferably
(*c*) 96 " " " " amyl alcohol to 4 of acid.

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[1] Arnold and Waterhouse, *Journal*, Iron and Steel Inst., 1903, Vol. I, p. 136; E. F. Law, *Journal*, Iron and Steel Inst., 1907, Vol. II, p. 94; Fay, *Proceedings*, Am. Soc. Test. Mats., Vol. VIII, p. 74 (1908).

[2] Igevsky, *Rev. de Met.*, Vol. II; Lejeune, *Rev. de Met.*, Vol. III, p. 426.

3. Near the eutectoid point, that is, 0.6 to 1.0 per cent of carbon, it is often difficult to distinguish between thin envelopes of ferrite and cementite. This difficulty can be overcome by etching with a solution of sodium picrate, which turns cementite dark brown or black but does not color the other constituents. The solution is made by adding 2 parts of picric acid to 98 parts of a solution containing 25 per cent of caustic soda, and is used at 100° C.[1]

4. In order to interpret the results of such an etching, they should be compared with standard etched specimens.

5. In the case of hardened and tempered steel the indications are less decisive than in the case of unhardened steel, probably because the former class has been studied less than the latter. Coarse grain, segregation of constituents, presence of oxide, etc., are all signs of bad material. For etching use a solution of 4 parts of nitric acid, specific gravity 1.42, in 96 of amyl alcohol. The time needed has to be found by trial in each case. Hence etch for 5 seconds, examine, re-etch if necessary,[2] etc.

MACROSCOPIC EXAMINATION.

6. Macroscopic examination shows up defects due to segregation, blowholes, piping, and the like, and when used in connection with microscopic examination yields valuable information. A section is cut with a saw, filed smooth, and polished with No. 0 and No. 00 emery paper; it is then ready for etching.

Quite a number of etching reagents have been used[3] to develop the structure. Whichever solution is chosen, the specimen is first carefully washed with a strong caustic potash solution, well rinsed under the tap, and then immersed in the etching solution. The following may be mentioned:

(*a*) Freshly prepared solution of 20 g. of I and 30 g. of KI, in 1000 g. of water.

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[1] Kourbatoff, *Rev. de Met.*, Vol. III, p. 648.

[2] Kourbatoff, *Rev. de Met.*, Vol. III, p. 648; Lejeune, *Rev. de Met.*, Vol. III, p. 426; Heyn, Mitt. aus dem Kŏnig. Materialsprŭf. Gross-Lichterfelde, West, 1906, 29.

[3] Fremont, *Rev. de Met.*, Vol. V, p. 669. Ast, International Assoc. Test. Mats., 1907, Fourth Congress, Problem 2.

(*b*) Dilute HCl or H_2SO_4 up to 30 per cent acid, using the 1.2 and 1.84 specific gravity respectively.
(*c*) Nitric acid, from 10 to 30 per cent of the 1.42 specific gravity[1] acid in 90 to 70 per cent of water.
(*d*) Concentrated HCl, specific gravity 1.2.
(*e*) A solution of 10 or 12 parts of double copper-ammonium chloride in 90 or 88 parts of water.

To bring out the structure of wrought iron rapidly, (*d*) is used, while (*c*) or (*b*) will bring it out more slowly.

For steel, first etch with (*a*), which shows up the segregation of carbon very well. Take care not to over-etch; 5 seconds is enough for some materials. To show up the impurities and the segregation of MnS, slag, etc., (*d*) acts quickly, but (*b*) gives better results though taking longer.

Some prefer light etching, say after 1 or 2 minutes, but an older method is to etch with (*b*) very deeply, indeed to a depth so great that several hours may be needed to reach it. In this way the segregation of the carbon and the impurities like slag and MnS are shown simultaneously. A picture of the object thus etched can be had by treating it like an engraving, that is, inking it with printer's ink, and printing on white paper directly from it. A common letter-copying press is convenient for this printing.

[1] Stead, *Proc. Cleveland Inst. of Engrs.*, Sept., 1906, p. 3.

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